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ASTRONOMY.—*Simon Newcomb, 1835–1909.*[1] EDGAR W. WOOLARD, United States Weather Bureau.

Two and a half centuries ago, Sir Isaac Newton presented convincing evidence that the force which holds the moon in its orbit is identical with the force that causes unsupported bodies near the surface of the earth to fall, and that this force conforms to the inverse square law. On the basis of this evidence and Kepler's empirical laws of planetary motion, Newton proposed the hypothesis of Universal Gravitation. From the general Laws of Motion (also formulated by Newton on the basis of his own and Galileo's work) and the Law of Gravitation, developed Celestial Mechanics, one of the greatest achievements of the human intellect.

The problems of celestial mechanics have always been a constant challenge and a source of inspiration to the mathematician and to the astronomer; and among those who have contributed to this difficult and intricate subject, will be found some of the most illustrious names in the history of the mathematical sciences. Among the select few who have been outstanding masters of the field, none ranks higher than Simon Newcomb, the one hundredth anniversary of whose birth occurred in 1935.

Simon Newcomb was one of the most notable men of science that America has ever produced; and his life cannot fail to be an inspiration to others—it is a story of boyhood dreams and ambitions, fulfilled by patient and persevering self-effort. He early formed the conviction that one should choose that sphere in life to which he was most strongly attracted and for which his faculties best fitted him. He himself was irresistibly attracted to celestial mechanics; it seemed to him to embody the highest intellectual power to which man had ever attained—from merely the positions of the celestial bodies in the sky, as observed from night to night, and on the basis of the single fact that each of these bodies is attracted by all the others, as stated

[1] Presented before the Maryland-District of Columbia-Virginia Section of the Mathematical Association of America, College Park, Md., December 7, 1935. Received December 17, 1935.

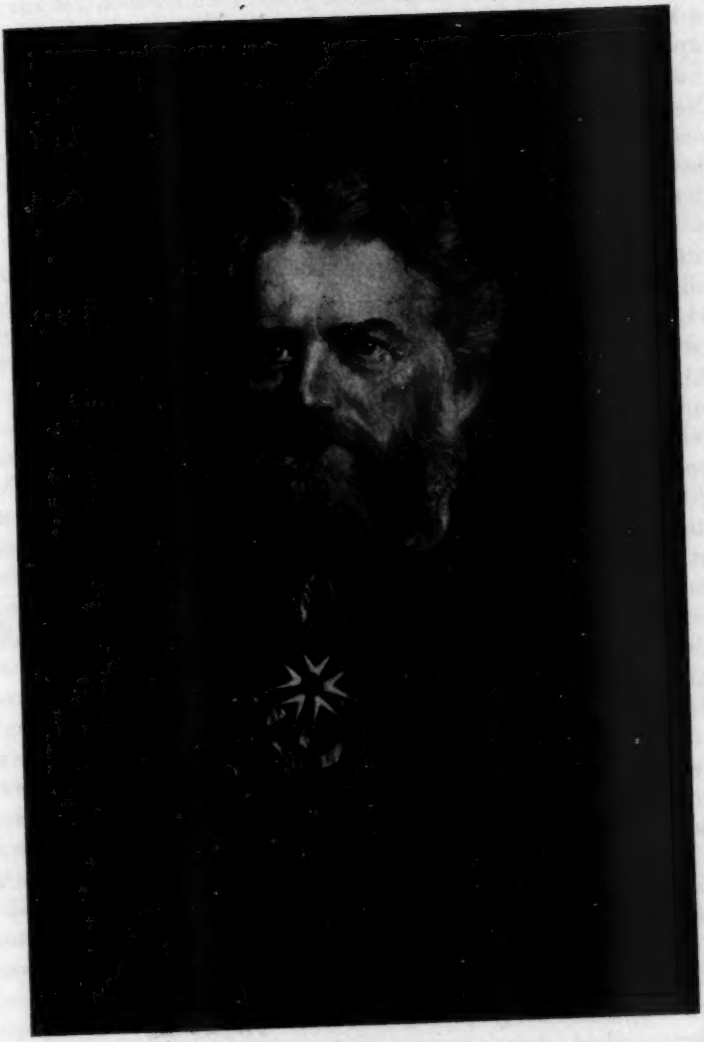
by the law of gravitation, the astronomer is to weigh these mighty bodies, determine the vast orbits in which they are moving in space, predict their majestic motions during future time, determine what changes of form and position their orbits will undergo through countless ages, make maps showing exactly over what cities and towns on the surface of the earth the shadow of the moon, during an eclipse of the sun, will pass fifty years hence or over what regions it passed centuries ago. To thousands of men who could achieve success and wealth in almost any walk of life, to hundreds who could wield empires, there would be but one who could succeed with this impressive problem—those who have done it are the select few of the human race—"Nearer the gods no mortal may approach."

Simon Newcomb was born March 12, 1835, at Wallace, on the north coast of Nova Scotia; the centenary of his birth was appropriately commemorated on August 30, 1935, when a cairn erected by the Historic Sites and Monuments Board of Canada was unveiled there by his daughter, Mrs. Joseph Whitney, of Washington, D. C., in the presence of many notable officials.

Newcomb's father was a country school teacher, an occupation which in those days meant an almost nomadic life, and Newcomb's childhood and boyhood were spent in various parts of Nova Scotia and Prince Edward Island. He was unusually strong of body, mind, and character, rather precocious, and had a conquering power of mental concentration. He received very little formal schooling; when he attended his father's school at all, he came and went with entire freedom, but he knew the alphabet at the age of 4, began arithmetic at 5, and geography at 6. He avidly read a work on astronomy before he was 10 years old, and was greatly attracted by the subject. Without the guidance of an instructor, he eagerly studied algebra, natural philosophy, and navigation, mostly from old books that had belonged to his grandfather; and he became enraptured with Euclid at the age of 15.

He was uncommonly deficient, however, in skill at any kind of manual labor, particularly that required on a farm; and because of the conditions of life at that time and place, this shortcoming, combined with the lack of appreciation by the people around him of his taste for learning, made his boyhood one of sadness. From reading, he gradually formed a vague conception of a different world—"a world of light," as he expresses it in his *Reminiscences*,[2] "where dwelt men

[2] SIMON NEWCOMB. *Reminiscences of an astronomer*. Boston. 1903.



SIMON NEWCOMB

who wrote books, and people who knew men who wrote books, where lived boys who went to college and devoted themselves to learning"—and he longed to get into this world. No possibility of doing so presented itself, however; and circumstances led him to apprentice himself at the age of 16 to a physician of Moncton, New Brunswick.

Newcomb soon discovered that this physician was only a dishonest quack, from whom he could obtain nothing; and after two wasted years, he made his escape by running away. After a painful and difficult month, he finally reached Salem, Massachusetts, where he was met by his father who had meanwhile sought his fortune in the United States after the death of Newcomb's mother. His father finally located in eastern Maryland; and here at the beginning of 1854, Newcomb, at the age of 19, became a country school teacher. He seems to have been successful in that work, though he writes that, looking back, he is deeply impressed with the good nature of the people in tolerating him in the position.

While teaching, he spent every spare hour studying all the books on mathematics and astronomy that he could secure or to which he could gain access, inclusive of Newton's *Principia*. He frequently visited the city of Washington during the next few years. Here he went as far as the gate of the Naval Observatory, and looked wistfully in, but feared to enter. He heard for the first time of the Smithsonian Institution, and its library proved to be a rich attraction; in May, 1856, he got permission to climb into the gallery of this library and see the mathematical books. "Here I was delighted to find the greatest treasure that my imagination had ever pictured—a work that I had thought of almost as belonging to fairyland. And here it was right before my eyes—four enormous volumes—'*Mécanique céleste*, by the Marquis de Laplace, Peer of France; translated by Nathaniel Bowditch, LL.D., Member of the Royal Societies of London, Edinburgh, and Dublin'." He secured special permission to take with him the first volume of this great work of which he had so long been dreaming, and he carried it in triumph to his little schoolhouse; he found most of it quite beyond his powers at the time, but this fact served only as an incentive to continued effort.

In 1855, when 20 years old, Newcomb published his first paper: A correspondent of a newspaper had written a long letter to refute the Copernican theory; the arguments, though wholly fallacious, seemed to Newcomb to appear so plausible that he was much alarmed lest the world's belief in the Copernican doctrine be severely weakened, and so he hastened to the rescue with an answer pointing out

the fallacies. His name in capital letters printed at the bottom of his article filled him with a sense of temerity at having perhaps intruded where he might not be wanted; but it brought him the presentation of a book of *Tables and formulae* from Col. Abert, and a letter from J. Lawrence Smith (afterward a member of the National Academy) transmitting a copy of a pamphlet on a theory of the origin of meteorites, and asking Newcomb's opinion on the subject. "I had not yet gotten into the world of light. But I felt as one who, standing outside, could knock against the wall and hear an answering knock from within."

Newcomb soon became acquainted with Joseph Henry, Secretary of the Smithsonian Institution, and with J. E. Hilgard, assistant in charge of the Coast Survey; he had never before looked upon a real live person of eminence in the scientific world, and had often wondered whether there were any possibility of making the acquaintance of so great a man as Joseph Henry. His reception by Henry and Hilgard was most delightful; and it was through their interest that he secured an appointment, when not quite 22 years old, as computer in the office of the American Ephemeris and Nautical Almanac, then located at Cambridge, Mass. Newcomb writes in his *Reminiscences:* "I date my birth into the world of sweetness and light on one frosty morning in January, 1857, when I took my seat between two well-known mathematicians [Joseph Winlock and John D. Runkle] before a blazing fire in the office of the 'Nautical Almanac'." His impressions of Henry and Hilgard, and of Winlock and others in the Almanac Office, were fully up to the most sanguine of his boyhood conceptions of men of science.

His duties required five hours a day, and his salary was $30 a month. He enrolled as a student of mathematics in the Lawrence Scientific School in Harvard College, studying under Benjamin Peirce, and received the B.S. degree the following year.

Newcomb was not satisfied at the prospect of doing nothing more than make routine calculations with formulae prepared for him by others; indeed, not yet having mastered the *Mécanique céleste,* he was almost disappointed to find that he was considered qualified for a position in the Nautical Almanac Office, but he consoled himself with the reflection that the ease of the work would not prevent him from working his way up. From this beginning he rose rapidly to a position of commanding eminence in mathematical astronomy, perhaps the most difficult field of human knowledge; and except for the one year at Harvard, he was self-taught. His original contributions

to celestial mechanics had already begun when his paper *On a method in dynamics*, dated April 2, 1858, appeared in Gould's *Astronomical Journal;* and his productivity continued uninterruptedly from that time to his death, 51 years later.

On October 7, 1861, Newcomb was appointed professor of mathematics in the U. S. Navy, for service at the Naval Observatory in Washington. His tastes and talents were in mathematical, rather than observational, astronomy; and he had applied for this position (on the recommendation of B. A. Gould, the first leading astronomer whose acquaintance he had made) only because it was desirable to provide for the future. He was without any experience or knowledge of astronomical observing; but he applied himself with diligence, and the results of his work with several different instruments during the next 10 years give abundant evidence of his energy and ability as an observer, and his remarkable breadth of view and power in planning and executing systematic and effective observing programs and in reducing and discussing the observations. There is no doubt that his experience in observational astronomy was of great value in his later theoretical work; he was unequaled in the comparison of theory with observation, and in the deduction of valuable results from large masses of data.

Newcomb's observational work did not wholly cease until about 1875; but several years previous to that time, the discrepancies between the observed positions of the moon and the positions computed from Hansen's Lunar Tables had become a serious matter; and at Newcomb's request, he was relieved from regular observing duties about the end of 1869, in order to conduct an investigation into the motion of the moon. The Lunar Theory developed into the leading interest of his life, and it received his best efforts during much of the time from 1870 to his death.

In 1877, Newcomb was appointed Director of the Nautical Almanac, and held that position until his retirement, devoting himself to mathematical astronomy which he had most at heart. It is impossible here even to mention all of his leading contributions to celestial mechanics and his many invaluable services to astronomy, to say nothing of his comparatively minor contributions, and his interests and activities in other fields; the complete bibliography of his writings[3] contains 541 titles, including 318 pertaining to astronomy, 35 to mathematics, 42 to economics, and 146 on miscellaneous

[3] R. C. ARCHIBALD. *Simon Newcomb: Bibliography of his life and Work.* Mem. Nat. Acad. Sci., xvii, First Memoir, Pt. II. 1924.

subjects that comprise even fiction! Attention must here be confined to his greatest project, the construction of new theories and tables for the motions of all the principal bodies of the solar system; this undertaking was one which he had long cherished, and upon assuming charge of the Nautical Almanac was enabled to put into execution.

A reconstruction of the lunar and planetary theories and tables was then badly needed, because the precision of astronomical observations had come to exceed the accuracy of the existing mathematical theories of the celestial motions. The computed motions did not represent the actual motions exactly, and the deviation of prediction from observation was constantly increasing. It is true that the discordance between theory and observation was not large enough to be of practical importance in the applications of astronomy; but if the celestial motions are produced solely by gravitational forces that act in conformity with Newton's Law, then a mathematical theory of the motions developed from this hypothesis should represent the observations exactly, over any period of time, and it is of the utmost importance to determine whether any observed discrepancies are due to some inadequacy of that hypothesis, or merely to imperfections of the mathematical theory.

If the solar system were composed of only the sun and a single planet, then the orbit of that planet would be an exact ellipse that would never change its form, size, or position. Actually, however, each of the planets and satellites moves in an exceedingly irregular and ever-changing path, because of the disturbances produced by the attractions of all the other bodies in the system. None of the departures from regular elliptic motion is very great; but the longer and the more accurately the motions are observed, the more complicated they are found to be. Now, there long had been no question, of course, that these irregular motions of the planets around the sun, and those of the satellites around the planets, are at least *very nearly* in accordance with Newton's law of gravitation; but the important question is whether the mutual gravitational attractions given by Newton's Law *completely* explain *all* the manifold irregularities in the actual motions that can be detected by observation.

To answer this question, long continued series of observations of the utmost attainable accuracy are first necessary, to determine with as much precision as possible how each body *does* move; and next, it is necessary to make a theoretical calculation of how each *would* move under only the Newtonian gravitational attractions of all the others, to the same degree of accuracy as the available observations.

Serious difficulties are encountered in both of these steps; and it is not easy to determine with certainty the significance of differences between theory and observation.

In the first place, accurate observations are difficult to obtain with even the finest instruments—untiring industry and great skill are required. Some allowance must always be made for inevitable errors of observation; and to combine observations made at different times and places, by different observers with different instruments, into a homogeneous whole for comparison with theory, is a task that calls for rare ability.

In the second place, the mathematical theories of the celestial motions are of a complexity almost beyond conception: It is well known that the general solution of the problem of even as many as three bodies moving under their mutual gravitational attractions cannot be obtained in any usable form. In the case of the planetary system, the very special circumstance that one of the bodies—the sun—dominates the entire system, permits an approximate solution of any required degree of accuracy to be obtained, valid over a more or less limited interval of time and in a form suitable for numerical calculation, but only at the cost of tremendous labor when the approximation is to be pushed to the accuracy of modern astronomical observations. Single formulae that fill dozens of printed quarto pages, and require months or even years to derive, are not unusual; the final equations that represent the motion of the moon contain over 1400 terms, and to obtain them is almost the work of a lifetime.

Only three times in the entire history of astronomy has anyone had the courage to undertake the systematic construction of complete theories for all the principal bodies of the solar system: The first attempt was by Laplace; his results are contained in the immortal *Mécanique céleste*, and upon them were founded the tables by Lindenau and Bouvard which remained in use for over 50 years. Laplace, however, developed the equations to only a low order of approximation; they were sufficient at that time, and demonstrated the agreement of the celestial motions with Newton's Law to a first approximation, but during the first half of the nineteenth century the development of precision astronomy under the leadership of Bessel, and the accumulation of further observations, led to a need for more accurate theories. The task was undertaken by Leverrier, one of those who had calculated the position of the planet Neptune prior to its telescopic discovery. During the 22 years from 1855 to his death in 1877, Leverrier succeeded in publishing new theories for all the

major planets; his work marked an epoch in gravitational astronomy, and resulted in greatly improved planetary tables, but it still left much to be desired, and deviations of the planets from their tabular positions soon began to appear.

Newcomb therefore set himself, at the age of 42, the task of again developing improved theories of the celestial motions, free from the defects of the previous investigations. The existing tables of the sun, moon, and planets, the catalogues of star positions, and the values of the fundamental astronomical constants that must be determined from observation, were then in a chaotic state; uniformity, and even consistency, were largely lacking. Newcomb planned the construction of theories and tables for all the major planets, the moon, and the other satellites, with an accuracy comparable to that of modern observations, and based on uniform and consistent values of the fundamental constants that themselves should be accurately determined from all existing observational data. It is practically impossible to effect any adequate conception of the appalling magnitude of this monumental project; and even an examination of the published results gives no adequate impression of the intricacy and complexity of the work, or of the immense labor involved in the execution of the program of lunar and planetary investigations which Newcomb mapped out. The determination of the fundamental constants involved the discussion of all observations of worth ever made on the positions of the sun, moon, and planets at the 13 leading observatories of the world since 1750; the number of meridian observations of the sun, Mercury, Venus and Mars alone was 62,030, and merely this part of the work was probably of greater magnitude than any single astronomical investigation ever before undertaken by one individual, although the final results are embodied in a modest octavo volume of only 200 pages—one of the classics of astronomy.[4]

For twenty years, driven by untiring energy and singleness of purpose, and sustained by an unusual power of continuous work, Newcomb devoted himself, solely in the interests of astronomical science, to this colossal task. Needless to say, it could not be performed without aid; not only is a corps of computers necessary, but also assistants with technical ability are needed. Newcomb himself emphasizes this; and he gives due credit, in many formal acknowledgments in his papers and on the title pages of his monographs, to his assistants,

[4] SIMON NEWCOMB. *The elements of the four inner planets and the fundamental constants of astronomy.* Supplement, American Ephemeris and Nautical Almanac for 1897. Washington, 1895.

while in his *Reminiscences* he pays high and generous tribute to those who aided him: The most difficult part of the whole program, the theory and tables of the giant planets Jupiter and Saturn, was assigned to George William Hill, whom Newcomb refers to as easily the greatest master of mathematical astronomy during the last quarter of the 19th century, and who labored incessantly for 10 years on the intricate calculations required by reason of the large masses and mutual proximity of these two great planets. Newcomb writes: "And here was perhaps the greatest living master in the highest and most difficult field of astronomy, winning world-wide recognition for his country in the science, and receiving the salary of a department clerk. I never wrestled harder with a superior than I did with Hon. R. W. Thompson, Secretary of the Navy, about 1880, to induce him to raise Mr. Hill's salary from $1200 to $1400." Hill himself took little interest in this matter—"He did not work for pay, but for the love of science. . . . That I could not secure for him at least the highest official consideration is among the regretful memories of my official life." Of Cleveland Keith, Newcomb says: "Without his help, I fear I should never have brought the tables to a conclusion."

The completion of Newcomb's great program was imperiled by his automatic retirement on March 12, 1897, at the age of 62, accompanied, unfortunately, by circumstances that were not to the credit of those responsible for them and which forced him to cease work on the uncompleted project. Eventually, however, the planetary tables were completed and published, and a star catalogue issued, by the Nautical Almanac Office, partly under Newcomb's supervision. His investigations of the motion of the moon had to be left unfinished, but were later completed during the last six years of his life under the patronage of the Carnegie Institution; the manuscript was finished less than a month before he died. For several months before his death on July 11, 1909, at the age of 74, Newcomb was aware that his days were numbered, and he devoted all his energy, often while in great suffering, to the completion of the lunar work. No lunar tables were constructed, however; and little was ever accomplished with the other satellites in the solar system. The huge task of discussing the comparison of his planetary tables with observation, and all the problems arising therefrom, were left untouched. An enormous mass of material that had been gathered for future work was left, and has remained unused. A great volume of essentially completed work was never published—in particular, a complete exposition

of the investigations and theories on which the planetary tables were based has not appeared. Newcomb wrote in the preface to the tables: "The question to what extent these and other researches shall be completed and published is one the decision of which must be left to others." After a lapse of nearly 40 years, it is only too painfully evident what that decision was.

During the 15 years from 1882 to 1897, eight and a half quarto volumes of the *Astronomical Papers of the American Ephemeris*, a series established by Newcomb expressly for the publication of results connected with his program, were issued under his supervision; during the next 15 years, following his retirement, nothing further was issued, until in 1912 his last memoir on the motion of the moon was posthumously published; in the 23 years since then, two brief monographs and a star catalogue are all that have been added to this series. Except for three brief papers by various authors, the first eight and one-half volumes are made up of twenty-five great monographs by Newcomb himself, three extensive memoirs by Hill, and the theory and tables of Jupiter and Saturn, also by Hill. It is evident that, despite the invaluable assistance rendered by others, the credit for the work that was accomplished belongs to Newcomb; it was due to his ability and vigor in planning the investigations, developing methods and procedures, supervising and checking, and pushing the program ahead, that it was carried as far as it was.

The volumes of the *Astronomical Papers* that contain the results are among the most priceless treasures of astronomical literature; they are now in use in the preparation of the annual emphemerides issued by the principal countries of the world. In his prefaces to the volumes of tables, however, Newcomb writes regretfully: "On surveying the completed work the author is painfully conscious that in several points it fails to reach the standard he had set for it." He enumerates the principal causes of the defects, and calls attention to the fact that a future generation must reconstruct the work.

Newcomb had a facile pen; he wrote clearly, in excellent English; and not the least of his services to astronomy were his many superb popular books and articles. His commanding position in astronomical science was universally recognized, and he was the recipient of a long list of honors, including degrees from 17 universities, and numerous medals and prizes from learned bodies. He was somewhat reserved and unapproachable, and inclined to be gruff, which sometimes led to an erroneous impression of him on the part of those who had not

come to know him; but his personal characteristics, as well as his scientific achievements, won many high tributes at the time of his death.[5]

CHEMISTRY.—*A pH conversion chart.*[1] W. H. Goss, Washington, D. C. (Communicated by F. G. BRICKWEDDE.)

A conveniently arranged chart or graph is useful to biologists and chemists in saving much time when converting emf values to pH readings in measurements on culture media and other solutions with hydrogen, glass, or quinhydrone electrodes and 0.1*N*, *N* or 4.1*N* (saturated) KCl-HgCl reference standards. The stoichiometric and mathematical equations correlating pH and emf values are rather complicated with certain types of electrodes and with special reactions involving, for example, oxidation-reduction. Several constants and variables may be involved in some cases, which must be placed in the equations correctly both as to sign and magnitude. The temperature-emf coefficient of each electrode must be applied. Frequently there is temporary instrumental or electrode hysteresis arising, for example, from electric leaks through moisture on the surface of the potentiometer or leads, or from irregular changes in temperature and activity of reference standards. Recognition and interpretation of these errors require detailed theoretical background and extensive experience beyond the scope of this paper. Such errors obviously cannot be corrected by a single graph or any other simple method. The mathematical expressions correlating emf and pH involve exponential functions which can be solved by use of logarithms or a slide rule. As many scientists in biology and chemistry and factory workers find such calculations foreign to their daily experience, it is believed that a chart will be helpful in work with some of the more commonly used electrode systems when free from the above mentioned errors.

Fig. 1 gives the variation in emf and pH values with temperature for several of these electrode systems. When made about 18 inches wide and 14 inches high the pH values from 0 to 14 can be read to 0.01 with a maximum error of ± 0.02 between 15° and 30°C. An $8'' \times 10''$ photograph can be read to 0.02 pH. This covers the ranges of temperature and the precision needed in most routine measure-

[5] See the Memorial Addresses read before the Philosophical Society of Washington. Bull. Phil. Soc. Wash. 15: 133–167. 1910.

[1] Received July 15, 1935.

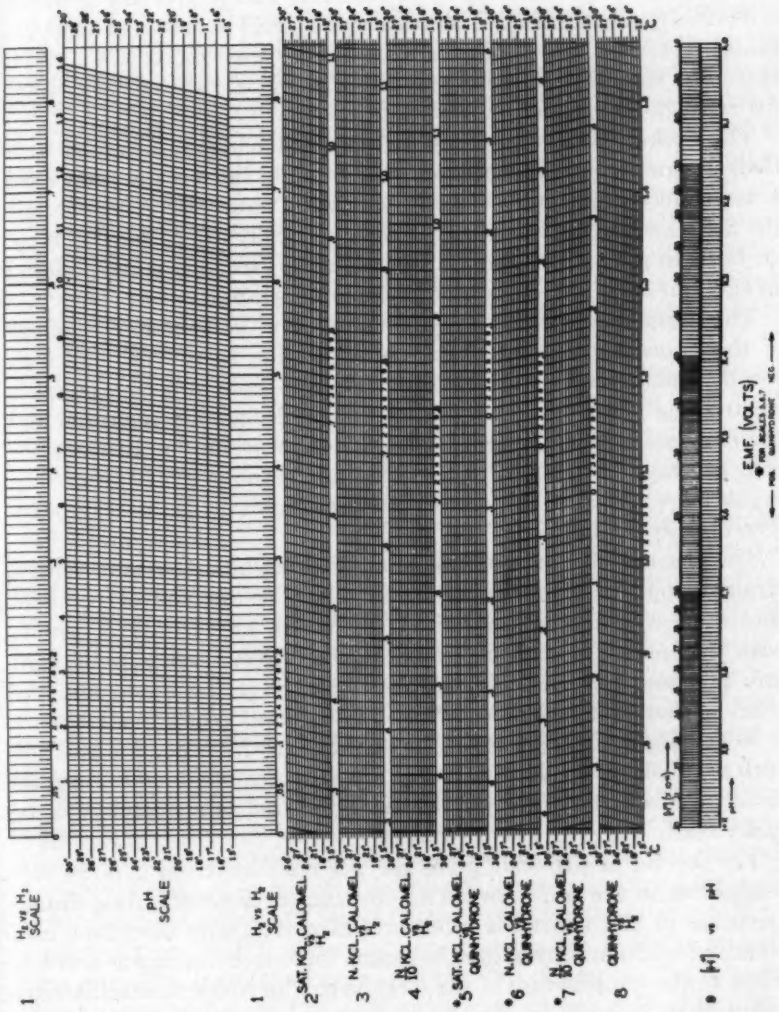

1 H_2 vs H_2 SCALE
pH SCALE
1 H_2 vs H_2 SCALE
2 SAT. KCL. CALOMEL H_2
3 N. KCL. CALOMEL H_2
4 $\frac{N}{10}$ KCL. CALOMEL H_2
*5 SAT. KCL. CALOMEL QUINHYDRONE
*6 N. KCL. CALOMEL QUINHYDRONE
*7 $\frac{N}{10}$ KCL. CALOMEL QUINHYDRONE
8 QUINHYDRONE H_2
* [H] vs pH
EMF. (VOLTS)

Fig. 1.—A pH conversion chart.

ments. Although the saturated KCl-HgCl reference electrode is perhaps most widely employed, because it has practically no contact potential against most unknowns, the 0.1*N* and *N* KCl-HgCl standards are frequently used with a saturated KCl solution or agar gel bridge between the calomel and hydrogen electrodes. The graph therefore includes all these systems with no corrections necessary for contact potentials.

The entire chart is made up of ten small horizontal graphs with their designations at the left side. The top and third scales numbered 1 are merely duplicates of the fundamental emf scale. They permit the accurate placing of a straight edge vertically at the same voltage on both to get the reading on the pH scale (second) corresponding to this emf or to any other emf in the lower graphs.

The lower scales, No. 2 to 8 inclusive, give the total emf readings of the indicated electrode pairs corresponding to pH values which can be read directly on the pH scale. The left-hand upper or reference electrode is *positive* (+) to the lower or hydrogen ion electrode and the emf readings in the graphs are therefore *positive* in all cases except in graphs 5, 6 and 7 where the emf to the left of 0 (zero) are *negative* (−) because the quinhydrone electrode is the positive one. (See note at the bottom of the graph.)

The chart is first placed on a small drawing board or table with a straight top edge, preferably under glass, cellophane or celluloid sheets when cleanliness is desired. By use of an accurate T-square with transparent straight edges both ends of No. 1 scale are brought into positions perpendicular to the top edge of the board and the chart is then fastened down with thumb tacks. When the T-square is moved along the top edge of the board to any intermediate position such as at 0.5 volt on the No. 1 scale the pH corresponding thereto and to any emf on the lower graphs at the desired temperature can be easily read.

The second or pH scale gives the pH readings from 0 to 14 corresponding to the emf between a hydrogen (or glass or quinhydrone) electrode in the unknown solution and a duplicate electrode in a standard solution having unit hydrogen ion concentration or activity when at the temperature of the unknown. The contact potentials are assumed to be entirely eliminated. This enlarged pH scale is therefore especially useful in obtaining the pH of the unknown as follows: The standard emf (positive or negative) of the reference electrode *toward* any hydrogen ion electrode (Pt, glass, quinhydrone, antimony, etc.) in a *N* H^+ solution is algebraically subtracted from the total

emf (positive or negative) given by the unknown solution when measured with the same reference and hydrogen ion electrodes; the difference is an emf found on the No. 1 scale or its extension (to e.g. pH of −1 or 15). The vertical straight edge is run through this point and cuts the horizontal line in the pH scale corresponding to the temperature of the unknown solution at a point which is the pH of the unknown. For example if a saturated calomel reference electrode is +0.245 volt toward a Pt-H_2 electrode in *N* H^+ solution and +0.745 volt toward the Pt-H_2 electrode in an unknown solution, the difference is 0.500 volt. If the saturated calomel electrode is −0.453 volt toward a quinhydrone electrode in *N* H^+ solution and +0.047 toward the quinhydrone electrode in an unknown solution, the difference is $+0.047-(-0.453)=+0.500$ volt. Such a difference of +0.500 volt on the No. 1 scale corresponds to pH 8.66 if the temperature of the unknown is 18°C. and 8.32 if it is 30°C.

The slopes of the emf lines in graphs Nos. 2, 3, 4, correspond to the temperature coefficients of the 4.1*N* (saturated), 1*N*, and 0.1*N* KCl-HgCl electrodes, −0.00076, −0.00025, and −0.00008 volts per degree, respectively, referred to the hydrogen electrode having zero temperature coefficient. In graph No. 8 the slope of the emf lines represents the temperature coefficient of the quinhydrone electrode, −0.00074 volts per degree, and in graphs Nos. 5, 6, 7 the slopes represent the difference between the temperature coefficient of the quinhydrone electrode and that of the particular KCl-HgCl electrode used. Since the temperature coefficients of the saturated KCl-HgCl and the quinhydrone electrodes are almost equal, −0.00076 and −0.00074 respectively, a cell composed of these has a very small temperature coefficient as shown by the nearly vertical emf lines in graph No. 5.

Graphs Nos. 2 to 8 are used as follows: The reference and hydrogen ion electrodes are assumed to be at the same temperature. Suppose that a total emf of 0.300 volt is measured at 18°C. in the electrode system used in graph No. 2. The straight edge is run from the point of intersection of the 18°C. and 0.3 volt coordinates of graph No. 2 vertically through the pH scale, note being taken that the straight edge gives the same reading on the two No. 1 graphs. The straight edge intersects the 18° line of the pH scale at pH 0.84; if the temperatures of both electrodes are at 30° the pH reading for 0.3 volt is 0.96. Likewise a total emf of 0.6 volt at 18° and 30°C. corresponds to pH 6.04 and 5.95 respectively; and 1.0 volt at 18° and 30°C. gives pH values 12.97 and 12.61.

It will be noted that in some of the different electrode systems Nos. 2 to 8 the pH increase with rise in temperature from 15° to 30°C. may be positive at one end of the pH scale, zero near the center, and negative at the other end. In other words we should be able to calculate for each electrode system the pH value at which the dE/dT slope for the total emf of two electrodes with different temperature coefficients is equal to the slope $dE/dt = -0.000198$ pH for the absolute pH scale. This pH reading remains the same whether both electrodes are at 15° or 30°C. This condition is satisfied when the single electrode potentials E_1 and E_2 for graphs Nos. 2 to 8 give

$$dE_1/dT - dE_2/dT = dE_H/dT = -0.000198 \text{ pH}$$

or

$$\text{pH} = (dE_1/dT - dE_2/dT)/(-0.000198) \quad \text{or} \quad d\text{pH}/dT = 0.0$$

By use of the temperature coefficients chosen above for various electrodes and the above equation it is calculated that for graphs Nos. 2 to 8 the pH values are 3.84, 1.26, 0.40, 0.1, −2.98, −3.33, and 3.74 respectively, at which the pH readings cannot change with equal rise in temperature of both electrodes. To the left of these pH values increase in temperature causes rise in the pH reading for the same emf and the reverse to the right. These pH points for graphs 6 and 7, namely pH −2.98 and −3.33 respectively, correspond to roughly 1000 N hydrogen ion concentrations which are beyond practical realization. For graphs 6 and 7, then, the pH always decreases for the same emf with rise in temperature.

It should be noted that in graphs Nos. 2 to 8 the slopes correspond to the difference between the temperature coefficients of the reference and hydrogen ion electrodes used. These are generally kept at the same, preferably constant, temperature such as 25°C., but even if they are at different temperatures the correct pH value can be read from graphs Nos. 2, 3, 4 and 8 by placing the vertical straight edge at the intersection of the observed emf and the horizontal ordinate for the temperature of the reference electrode used and reading off the pH scale at the intersection of the vertical straight edge with the horizontal ordinate for the temperature of the hydrogen ion electrode.

When the two electrodes are at different temperatures and neither has a zero temperature coefficient, as is the case when quinhydrone is used with a calomel electrode in graphs Nos. 5, 6 and 7, a correction for any difference in their temperatures must be applied to the emf reading before using the chart. The correction to be added to the emf reading is the *algebraic* change in the normal emf of the reference

calomel electrode when brought to the temperature of the quinhydrone electrode, and is easily applied as follows: The magnitude of the correction is the temperature coefficient of the calomel electrode multiplied by the difference between its temperature and that of the quinhydrone electrode. If the calomel electrode is at a higher temperature, this correction should be subtracted from the emf reading measured, before consulting the graph, because the calomel electrode temperature coefficients have negative values. If the calomel electrode temperature is lower than that of the quinhydrone electrode, the correction should be added to the reading. As an example assume that a quinhydrone electrode is at 28° and a 0.1*N* calomel electrode is at 18°, and that the emf reading of this cell is −0.136 volts. The temperature coefficient of the 0.1*N* calomel electrode is −0.00008 volts/degree. Then $(-0.00008)(10) = -0.0008$ volts or practically −0.001 volt. Then $-0.136+(-0.001) = -0.137$ volts for use on the chart. The corresponding pH reading on the 28° line of the pH scale and scale No. 7 is 3.74.

The glass electrode is used with so many combinations of internal and external calomel, AgCl-HCl and quinhydrone reference electrodes that the only general rule is to make all corrections for the reference standards (e.g. 0.1*N* HCl-HgCl, 0.1*N* HCl-AgCl, or 0.1*N* HCl-quinhydrone or Thompson's[3] metal coating) necessary to get the emf between the unknown solution on one side of the glass membrane and the pH standard ($H^+ = 1$ or 0.1*N* HCl with pH 1.07) on the other side and use this emf with graph No. 1 and the pH scale to get the difference in pH at the temperature of the glass electrode. This general procedure applies to the use of the chart with the antimony or any other hydrogen ion electrode or buffer standard.

The emf of the reference electrodes toward the normal hydrogen ion electrode and the pH values used in making the chart are those common today: namely, +0.2496 at 20°C. and +0.2420 at 30°C. for the saturated KCl-HgCl-Hg electrode; +0.2860 at 20°C. and +0.2835 at 30°C. for the *N* KCl-HgCl-Hg electrode; +0.3379 at 20°C. and +0.3371 at 30°C. for the 0.1*N* KCl-HgCl-Hg electrode; and +0.7029 at 20°C. and +0.6955 at 30°C. for the *N* H^+-quinhydrone electrode.

Graph No. 9 is a log scale added to make easy the calculation of hydrogen ion concentration from the pH reading. It gives only the mantissa (fraction) of the log as the characteristic (integer) is used by inspection as follows. A pH value such as 7.25 is the log (on base

[3] THOMPSON, M. R. Bur. Standards J. Research 9: 852. 1932.

10) of the *dilution* of the hydrogen ions, i.e., of the number of liters containing one gram equivalent H^+. As concentration (C_H) is the inverse of dilution (V_H in liters), for pH 7.25 $C_H = 1/V_H = 1/10^{7.25} = 10^{0.75}/10^8 = 10^{0.75} \times 10^{-8} = 5.63 \times 10^{-8}$. A graph such as No. 9 would ordinarily read from left to right in making the above calculation, familiar to those regularly employing logarithms, but by constructing the linear scale to read from right to left, the above calculation can be eliminated and the C_H corresponding to any pH value, or vice versa, can be read directly as follows: For pH 7.25 read off the fractional pH value 0.25 from right to left to get the corresponding number, 0.563 in this case. The H-ion concentration is this number multiplied by 10 to a minus power equal to the integer or whole number of the pH value, e.g., $C_H = 0.563 \times 10^{-7}$ or 5.63×10^{-8}. A pH value in integers alone (e.g., pH 7.0) gives directly a C_H value equal to 10 to the negative integer power (e.g., 10^{-7}).

A 14×18 inch enlargement of the pH conversion chart described can be used with a maximum error of ±0.02 pH unit. It should, therefore, be a valuable aid to biologists, chemists, and students engaged in pH measurements, both as a tool for conversion of routine emf measurements into pH values and as a guide toward a clear conception of the inter-relationships between the electrode systems commonly used in electrometric pH measurements.

ACKNOWLEDGMENT

The writer is indebted to Dr. S. F. Acree of the National Bureau of Standards for suggesting the preparation of such a general purpose pH chart, and to Mr. G. H. Lovins for aid in its design and construction.

PALEONTOLOGY.—*Nomenclatorial notes on fossil and recent Bryozoa.*[1] R. S. BASSLER, U. S. National Museum.

Taxonomic studies of the Bryozoa have interested the writer to such an extent that he recently published a bibliographic index of fossil and recent genera, giving the classification, genotypes, principal citations and other information useful to the specialist on this group.[2] Further researches have shown the necessity for additional changes in nomenclature which are recorded in the present paper.

[1] Published with the permission of the Secretary of the Smithsonian Institution. Received January 17, 1936.

[2] Part 67 of the *Fossilium Catalogus, Bryozoa Generum et Genotyporum Index et Bibliographia.* pp. 1–229, 1935.

Order TREPOSTOMATA Ulrich

Family BATOSTOMELLIDAE Ulrich, 1890

Stenoporella, n. gen.

Like *Stenopora* Lonsdale, 1844, save that instead of diaphragms numerous spines project from the walls into the zooecial cavity, and the beaded structure of the walls is nearly obsolete. *Stenophragma* Munro, 1912, has semidiaphragms projecting from one side of the wall only and has regularly beaded wall structure.

Genotype.—*S. romingeri* n. sp. Mississippian of Arkansas.

Stenoporella romingeri, n. sp. Figs. 1–3

Zoarium an explanate mass about 100 mm in diameter and 25 mm at the thickest portion, consisting of several superposed layers of zooecia, with surface smooth and clusters inconspicuous, the zooecia being nearly uniform in size. Zooecia angular, 8 in 2 mm, thick walled, with mesopores practically wanting. Large acanthopores of the type found in *Stenopora* occupy only the junction angles and average 2 to each zooecium. Diaphragms wanting, their place being taken apparently by semidiaphragms, which in this case appear as spines projecting into the zooecial cavity. These spines resemble similar projections in such genera as *Chaetetes* and *Favosites*, but the presence of *Stenopora*-like acanthopores and wall structure seems to justify the reference of the genus to the Bryozoa.

Occurrence.—Found by Dr. Carl Rominger at Cave Creek, Arkansas, in strata said to be of Chester age.

Holotype.—No. 53833, U. S. National Museum.

Order CYCLOSTOMATA Busk

Family CERAMOPORIDAE Ulrich, 1882

Haplotrypa, n. gen.

This new genus is proposed for various parasitic or discoidal species which have the ceramoporoid wall structure, namely of irregularly laminated tissue, but entirely lack the lunarium characteristic of most other genera of the Ceramoporidae. The apertures are direct, and externally bear a resemblance to the trepostomatous genus *Monotrypa* Nicholson, 1879. *Spatiopora* Ulrich, 1882, consisting of thin parasitic expansions with oblique cells and blunt acanthopores, is a related genus.

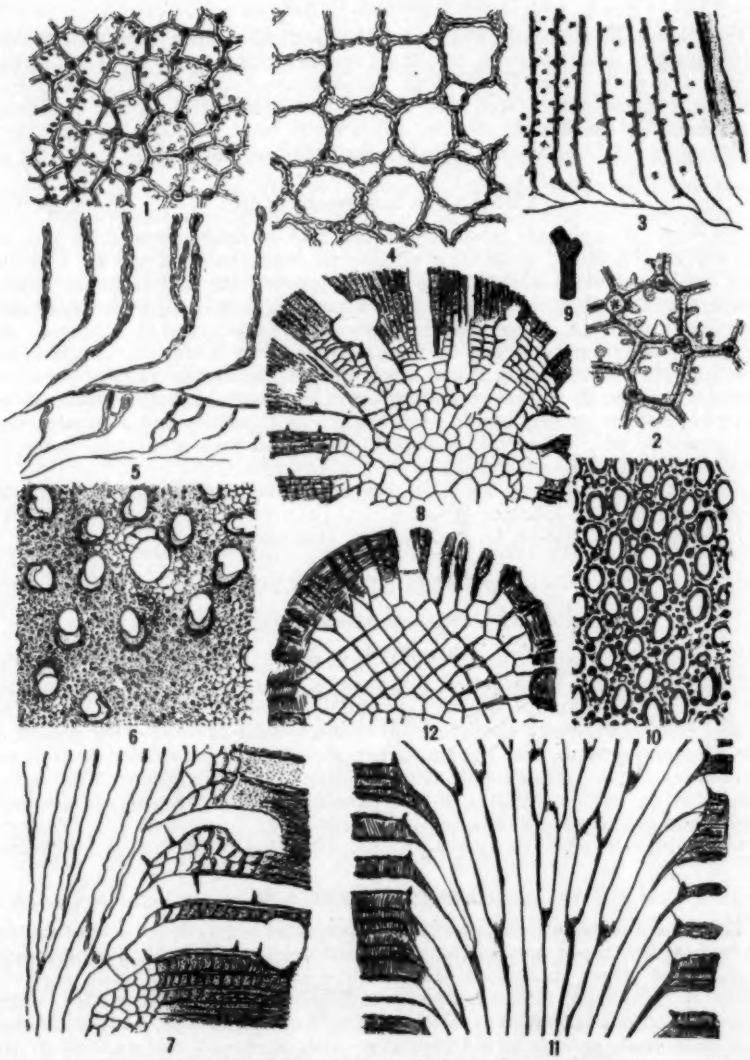
Genotype.—*Haplotrypa typica*, n. sp. Range, Ordovician to Devonian.

Haplotrypa typica, n. sp. Figs. 4, 5

Zoarium a lamellate expansion of superposed layers several centimeters wide and 4 or more mm in thickness. Surface smooth with inconspicuous maculae of larger zooecia, of which there are 3 in 2 mm while 4 of the ordinary ones occur in the same space. Zooecia angular, thin walled, sometimes in contact but often separated by narrow interspaces. In thin sections the laminated, ceramoporoid structure with apparent perforations in the walls is quite evident. Diaphragms are practically absent in both sets of tubes.

Occurrence.—Niagaran group (Osgood), Osgood, Indiana.

Holotype.—No. 92132, U. S. National Museum.



For explanation of Figs. 1–12, see bottom of opposite page.

Order CRYPTOSTOMATA Vine
Family RHABDOMESONTIDAE Vine, 1883

Rhomboporella, n. gen.

Solid, ramose Rhabdomesontidae with the zooecial tubes in the axial region regularly rhombic or quadrate in cross section. Superior hemiseptum and two sets of acanthopores, a large set at the end of the zooecia and a small one entirely surrounding them, well developed.

Genotype:—Rhomboporella typica, n. sp. Carboniferous of Bolivia.

The discovery of this type of structure in the Cryptostomata illustrates an interesting case of parallel development in two different orders of the Bryozoa, as a similar occurrence of rhombic or quadrate zooecia in transverse section is found in the Silurian genus *Rhombotrypa* Ulrich and Bassler 1904, and the Middle Carboniferous *Rhombotrypella* Nikiforova, 1933, belonging to different families of the order Trepostomata. End views of the axial part of the branches in these three genera are so similar as to lead to confusion, but the cryptostomatous characters of the present form are so evident that there can be no thought of close alliance. In each case the similarity is caused by the fact that the zooecia of the immature zone simultaneously at definite intervals develop new tubes and undergo a change in orientation of their sides. This process has been explained in detail by the authors of *Rhombotrypa*,[3] and it will suffice to say here that the rhombic or quadrate cross section is maintained by this concurrent development of new tubes.

Rhomboporella typica, n. sp. Figs. 9–12

Zoarium, a cylindrical, solid, smooth branch, 3 mm in diameter, dividing at intervals. Surface without distinct maculae but with areas of slightly larger zooecia having thicker walls. Zooecia elongate, polygonal, with walls thin to thick according to age, bearing two sets of acanthopores, one of distinctly larger size at the ends of the orifices, and the other of smaller granules ornamenting each wall. Zooecia in irregular quincunx, 6 to 7 in 2 mm measuring along the longer diameter.

Tangential sections reveal the thickened walls, the large and small sets of acanthopores and the few intervening mesopore-like areas. The vertical

[3] Smithsonian Miscellaneous Collections **47**: 44. 1904.

Figs. 1–3.—*Stenoporella romingeri* n. sp. 1, A tangential section through the mature region, ×18, showing the large acanthopores and the semidiaphragms in the form of blunt spines. 2, portion of the same, ×21. 3, vertical section, ×18, exhibiting the aspect of the semidiaphragms in this direction. Chester at Cave Creek, Arkansas.

Figs. 4, 5.—*Haplotrypa typica* n. sp. Tangential and vertical thin sections, ×18, illustrating the ceramoporoid wall structure and the absence of lunaria. Niagaran group (Osgood), Osgood, Indiana.

Figs. 6–8.—*Cliotrypa ramosa* Ulrich and Bassler, n. sp. 6, Tangential section, ×18, near the surface showing the normal zooecia and one of the ovicell-like forms, as well as the granose interspaces. 7, vertical section, ×18, of half of a branch with the ovicell-like expansions and the hemiphragms developed. 8, transverse thin section, ×18. The thin walled immature region and the mature zone with hemiphragms and expanded zooecia, are evident. Mississippian (New Providence shale), King's Mountain, Kentucky.

Figs. 9–12.—*Rhomboporella typica* n. sp. 9, zoarium, natural size. 10, tangential thin section, ×18, through the mature zone. 11, vertical section illustrating the origin of new tubes at regular intervals, and the superior hemiseptum. 12, transverse thin section, ×18, showing the rhombic form of the immature zooecia. Carboniferous of Chulpapampa, Bolivia.

section is with one exception that of a typical member of the Rhabdomesontidae with the superior hemiseptum well developed. The exception, as explained in the generic remarks, is the development of a rather wide immature or axial zone in which the zooecia originate new tubes simultaneously at regular intervals. In vertical fractures of a branch this is shown by alternating smooth and uneven spaces which when cut by the thin section give the aspect exhibited in Fig. 11. Transverse sections are unusually interesting as it is here that the quadrate or rhombic form of the immature zooecia is best exhibited. The end of a branch moistened and viewed under a hand lens shows this character equally well, and gives a ready clue to the species. The large acanthopores originate in the axial region for they are distinctly visible in transverse thin sections.

Occurrence.—Carboniferous of Chulpapampa, Bolivia.

Holotype.— No. 68813, U. S. National Museum.

Family FISTULIPORIDAE Ulrich, 1882

Cliotrypa Ulrich and Bassler, n. gen.

Fistuliporidae like *Fistulocladia* Bassler, 1927, that is, narrow, solid, cylindrical, smooth branches with ovicell-like inflations in the tubes which develop in addition well defined semidiaphragms projecting into the zooecial cavity in the mature region.

This genus originally distinguished and named by Dr. Ulrich and the writer in 1897 when specimens were distributed to various students, was defined by the junior author in the *Paleontology of Timor* 16: 49, 1929, but remained invalid because the genotype had not been figured. This is herewith corrected with the following description and figures.

Genotype.—Cliotrypa ramosa n. sp. Range, Mississippian and Permian.

Cliotrypa ramosa Ulrich and Bassler, n. sp. Figs. 6–8

Zoarium of small, solid, smooth, branching cylindrical stems, 2.5–4 mm in diameter, bearing oval zooecial apertures with strongly marked lunaria, separated by solid, granose interspaces and exhibiting large solid maculae at intervals of about 4 mm. Measuring lengthwise, 4 zooecia occur in 2 mm. In vertical thin sections, the zooecial tubes are thin walled in the solid axial region becoming thick walled in the mature zone and developing at intervals rather thick incomplete plates from alternate sides of the wall as hemiphragms in place of the ordinary diaphragms, and occasionally expanding into spherical, ovicell-like structures which then contract to normal size, or may appear as swollen prominences at the surface. The subsolid interspaces and the maculae are separated by vesicles and towards the surface are traversed by numerous small tubuli.

Occurrence.—Mississippian (New Providence shale), King's Mountain, Kentucky.

Holotype.—No. 92133, U. S. National Museum.

Order CHEILOSTOMATA Busk

The following changes in family, generic, and specific names are suggested in this order.

Family URCEOLIPORIDAE, new name

Proposed in place of Euthyridae Levinsen, 1909, invalid name, since *Euthyris* Hincks, 1882, is preoccupied by the fossil brachiopod genus *Euthyris* Quenstedt, 1869.

Genus **Euthyrisella,** n. gen.

Named in place of *Euthyris* Hincks, 1882, preoccupied by *Euthyris* Quenstedt, 1869.

Genotype.—Euthyris obtecta Hincks, 1882. Recent of North Australia.

Family CHEILOPORINIDAE, new name

The genus *Hippopodina* Levinsen, 1909, was described as possessing an endotoichal ovicell and the family Hippopodinidae was founded by him in 1909, based upon this character. However, the ovicell in the genotype, *Hippopodina feegensis* Busk, 1884, is hyperstomial, and the genera with endozooecial ovicell must be classified otherwise. The new family Cheiloporinidae is, therefore, proposed, based upon *Cheiloporina* Canu and Bassler, 1923, a genus with numerous species, ranging from the Eocene to the Recent. The family Hippopodinidae may be retained for the single type genus or future researches may show it to be related to the Schizoporellidae.

Adeona joloensis, new name

Proposed for *Adeona porosa* Canu and Bassler, 1929, from Jolo, Philippines, preoccupied by *Adeona porosa* Canu and Bassler, 1923, from the Miocene of Santo Domingo.

Escharoides erectoides, new name

Proposed for *Peristomella erecta* Canu and Bassler, 1920, from the Tertiary of South Australia, preoccupied by *Peristomella erecta* Canu and Bassler, 1920, from the Vicksburgian of Alabama, both species now being referred to *Escharoides.*

Callopora horniana, new name

Proposed to replace *Callopora crassospina* Canu and Bassler, 1923, from the Pleistocene of California, preoccupied by *Callopora crassospina* Canu and Bassler, 1920, from the Eocene of North Carolina.

Cellaria elongatoides, new name

Proposed in place of *Cellaria elongata* Canu and Bassler, 1928, from Morocco, preoccupied by *Cellaria elongata* Canu, 1908, from the Patagonian of Argentina.

Floridina voigti, new name

Name proposed for *Floridina bifoliata* Voigt, 1930, from the Danian drift of Anhalt, Germany, preoccupied by *Floridina bifoliata* Canu and Bassler, 1920, a Tertiary species from Mississippi.

Dacryonella minuta, new name

Proposed for *Dacryonella minor* Canu and Bassler, 1920, from the Jacksonian of Florida, preoccupied by *Dacryonella* (*Membranipora*) *minor* Hincks, 1885, a recent species.

Gemelliporina, new genus

Gemellipora Smitt, 1872, by the rules of nomenclature, is a synonym of *Pasythea* Lamouroux, 1871, so that the second group of species typified by *Gemellipora glabra* Smitt, 1872, retained under this name by Canu and Bassler, must be classified elsewhere. The new name *Gemelliporina* is, there-

fore, here proposed for species with keyhole-like aperture, hyperstomial ovicell and tremocyst frontal, with *Gemellipora glabra* Smitt, 1872, a common species of the Gulf of Mexico, as the genotype.

Figularia duvergieri, new name

Proposed for *Figularia carinata* Duvergier, 1924, from the Helvetian of Salles, France, preoccupied by *Figularia* (*Figulina*) *carinata* Waters, 1923, a recent species from the East Indies.

To the *Fossilium Catalogus* the following generic citations should be added:

Spirillopora Gürich, 1896. Lower Devonian

Gürich, Verh. d. Russ.-Kais. Mineral, Gesell. zu St. Petersburg, (2) XXXII, p. 213, 1896.

Genotype.—S. anguillula Gürich, 1896, idem, p. 213, pl. X, fig. 17. Poland. Unrecognizable. Figure shows only a twisted stem with cells in spiral rows.

Vetofistula Etheridge, Jr., 1917. Devonian

Etheridge, Jr., Geol. Surv. Queensland, Pub. No. 26, p. 17, 1917.

Genotype.—V. mirabilis Etheridge, Jr., 1917. Not recognizable.

Zeapora Penecke, 1893. Devonian

Penecke, Jahrb. d. kk. geol. Reichsanst. XLIII, p. 610, 1893.

Genotype.—Z. gracilis Penecke, 1893. Alps. Unrecognizable. A trepostome but illustrated by only a poor section.

PALEONTOLOGY.—*A new* Allagecrinus *from Oklahoma.*[1] EDWIN KIRK, U. S. Geological Survey.

The U. S. National Museum has recently acquired a number of Pennsylvanian crinoids from Mr. H. L. Strimple of Bartlesville, Oklahoma. Some of them are of considerable biologic and stratigraphic interest, and Mr. Strimple deserves much credit for discovering and calling attention to this material from a hitherto barren field. The most interesting crinoids collected are a suite of *Allagecrinus* preserving the arms. *Allagecrinus* and allied genera have been known for a long time from many parts of the world, and several hundred specimens have been collected. Up to the present, however, none has been found with the arms attached. The species itself proves to be new and is here described as *Allagecrinus strimplei*. Altogether 10 dorsal cups and 18 complete crowns, as well as several sets of dissociated arms, have been available for study.

[1] Published by permission of the Director, U. S. Geological Survey. Received January 29, 1936.

Allagecrinus strimplei, n. sp.

The species is comparable in size with the larger known species of *Allagecrinus* from the Pennsylvanian and Permian. The largest dorsal cup has a diameter of approximately 5 mm. The smallest individual is about one-half as large. The largest complete crown has a height of 12 mm. The other

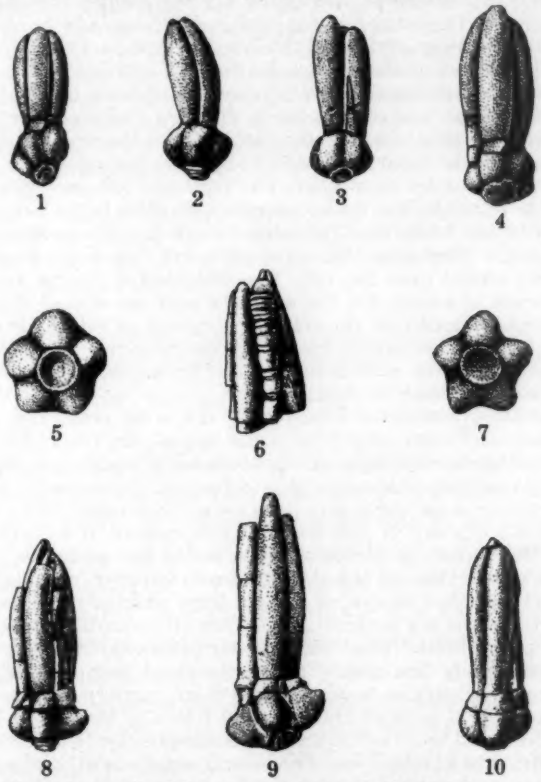


Fig. 1.—*Allagecrinus strimplei*, n. sp. Young individual in three-arm stage. Fig. 2.—Four-arm stage. Fig. 3.—Three-arm stage with incipient fourth arm appearing. Fig. 4.—Four-arm stage, primary arm in center and secondary arm to left. Figs. 5, 7.—Basal views of two dorsal cups showing variation in lobation. Fig. 6.—Proximal portion of column lying on a set of arms. Fig. 8.—Five-arm stage; primary arm in center; secondary arms to right and left. Fig. 9.—Largest complete crown; primary arms in center and to right; secondary arm to left. All figures are ×3. They have been drawn in pen and ink from photographs and are somewhat diagrammatic.

specimens are intermediate in size and yield a fair series of growth stages that are especially interesting as regards the development of the arms.

The dorsal cup is depressed bowl shaped, with a diameter approximately twice the height. The radials are tumid, giving the dorsal cup a distinctly pentalobate to substellate outline as seen from above or below. The basals form a pentagon approximately two-fifths the diameter of the cup. What

appear to be sutures within the basal circlet may be seen at times, but the almost complete coverage of the basals by the proximal columnal makes it impossible to identify and orient the basal elements with certainty. If sutures are present, as seems probable, one would expect three unequal elements. The radials are higher than wide. In very young specimens the radials are moderately convex. With increasing age the radials become more and more tumid. In the largest specimens each radial bears a large protuberance. In most cases the upper surface of this knob is flattened to concave as seen in profile. This is well shown in the drawings. The tumidity of the radials varies in amount and character as between individuals of nearly the same stage of development, and even between different radials of the same specimen. Based on the relative convexity of the radials the series of specimens in hand could readily be separated into two species, the younger specimens in one species and the older in another. The right and left posterior radials are but slightly notched by the first anal plate, so little in fact that it is difficult to identify the posterior interradius except in very well-preserved and carefully cleaned specimens. The anal plate notches more deeply into the right posterior radial than the left. The articulating face of each radial is produced inward as a shelf. On this shelf the position of each arm is marked by a depression bounded on the sides by converging ridges. The shelf supporting the arms is continuous except in the posterior interradius. In the posterior interradius the shelf is interrupted by a parabolic notch which in well-preserved specimens is clearly shown.

In the youngest specimens which have the arms preserved, three large arms are present. Later, additional arms appear. In the oldest specimens preserving the arms, five arms of approximately equal size are found. In the largest dorsal cup the converging ridges on the superior faces of the radials and the articulating facets indicate at least eight arms, with a possibility that a ninth arm is just beginning to appear. If so, this ninth arm would give three arms to one ray, which is the left posterior. The radials bearing two arms each are the left posterior, anterior, and right anterior. Owing to the fact that we do not have a large number of dorsal cups, and that where the arms are preserved they are often partially detached from the radials and shifted from their original positions, it is not possible to determine accurately the orientation of the three original arms.

The arms are variable in structure. The three primary arms seem to agree in being made up of a short first brachial followed by a very long second brachial. Additional brachials are added subsequently. The secondary arms have the short first brachial, but the second brachials are not so disproportionately long, and several shorter brachials make up the length attained by the two brachials of the three primary arms. An average of many measurements of the first brachials gives a length of 0.9 mm. In the primary arms the second brachials have an average length of 6.7 mm. In one ray where several brachials are preserved, presumably a secondary arm, the brachials give the following measurements: 1, 0.9 mm; 2, 1.7 mm; 3, 2.1 mm; 4, 2.6 mm. Another arm of the same type gives the following measurements for the brachials: 1, 0.9 mm; 2, 1.3 mm; 3, 1.6 mm; 4, 1.8 mm; 5, 2 mm. In the secondary arms the greatest variation in length seems to be found in the third brachial, measurements varying from 1.3 mm to 3.4 mm. The mature brachials have an average maximum breadth of 1.4 mm. The backs are strongly convex, and the surface is covered with fine granulations. The secondary arms as they first appear have flat or slightly convex backs, which gradually increase in convexity with age. The union of the first

brachial with the radial is weak, as is also the union between the first and second brachials. As a result the arms are seldom in true alignment and in their original positions.

Fortunately fragments of column have been found in such relationships with the *Allagecrinus* crowns as to leave no doubt as to their belonging together. The column figured lies on a set of arms and is incomplete in its proximal portion. The proximal columnals are thin and become narrower distad. This tapering proximal portion of the column is similar to that commonly found in the Flexibilia. Below the tapering columnals the character of the column changes completely. The columnals are beadlike, and the nodals are relatively large. The general aspect of the column is very like that of one of the young Flexibilia from the Devonian or Mississippian.

There is no described species of *Allagecrinus* with which *A. strimplei* may be confused.

Horizon and locality.—The specimens were collected by Mr. H. L. Strimple in the Dewey limestone (Pennsylvanian) near Dewey, Oklahoma.

Types.—The cotypes are in the Springer collection in the U. S. National Museum, No. S. 4126.

BIOLOGY.—*Food of Arctic birds and mammals collected by the Bartlett Expeditions of 1931, 1932, and 1933.*[1] CLARENCE COTTAM, U. S. Biological Survey. (Communicated by WALDO L. SCHMITT.)

On Captain R. A. Bartlett's three arctic expeditions in the summers of 1931, 1932, and 1933, alimentary material, mostly gullet and stomach or gizzard contents of 115 birds representing 21 species and one additional subspecies, was collected. This material, subsequently submitted to the Biological Survey for analysis, forms the basis for this paper. Fifty-three birds were secured on the first expedition during July and August from northwestern Greenland in the vicinity of Clavering Island, northward to slightly beyond the 74th parallel north latitude and between the 13th and 29th meridians west longitude. The second expedition returned with 20 birds from western and northern Greenland, northward to latitude 76° 33′. These birds, likewise, were taken during the months of July and August. Localities mentioned were Parker Snow Bay, Dalrymple Island, Cape York, Walstenholme, and North Star Bay in latitude 76° 33′. During the 1933 expedition, which extended from July to September, one weasel and five ground squirrels were collected in addition to 42 birds. Collections were made in the area between northern Hudson Bay and western Greenland. Localities recorded included Melville Peninsula; Duckett's Cove, Hudson Strait; Igloolik Island near Fury and Hecla Strait; Cape Frigid, Southhampton Island; and the open seas at latitude 61° north and longitude 64° 20′ west.

[1] Received February 11, 1936.

Even though the number of individuals and species in the collections is not so large as one might wish, they are of more than ordinary importance as they represent a far northern area in which but little critical study of the food habits of birds has previously been made. The majority of these species were poorly represented, or even entirely wanting in the "stomach files" of the Biological Survey.

While the writer examined the majority of the stomachs submitted, generous assistance in this regard was received from A. L. Nelson, Cecil S. Williams, Leon H. Kelso, and F. H. May, all of the staff of the Biological Survey food-habits research laboratories. Specialists who aided by making identifications of questionable material include: Dr. Waldo Schmitt and Clarence Shoemaker, of the U. S. National Museum, on crustaceans; F. M. Uhler, of the Biological Survey, fishes; Wm. B. Marshall, of the U. S. National Museum, mollusks; J. R. Malloch, of the Biological Survey, two-winged flies (Diptera); and Dr. R. V. Chamberlin, of the University of Utah, spiders.

A summary of the food percentages by volume as determined from the analysis of stomachs, gullets, or crops of the birds collected on these expeditions follows:

Gavia stellata (Pontoppidan). Red-throated Loon.

Five adult and two juvenile stomachs of the red-throated loon provide convincing evidence that the birds' piscivorous tendencies dominate. Two adult stomachs were taken from Clavering Island, northeast Greenland, two from Igloolik Island, northwest Greenland, and one from Cape Frigid, Southhampton Island, Northwest Territory. Four of these adult birds had made their entire meals on small coarse fish, largely Gadidae (? *Boreogadus saida*), sculpins (Cottidae), and tomcod (*Microgadus tomcod*), while the other had made 80 percent of its meal on sculpins (Cottidae), tomcod (*Microgadus tomcod*) and sand launce (*Ammodytes* sp.). The remaining 20 percent of the meal of this bird consisted of 54 polychaete (marine) worms, apparently a species of Nereidae.

The food of these five adult birds would be summarized as follows: Cottidae, 34.2 percent; tomcod (*Microgadus tomcod*), 4.8 percent; *Ammodytes* sp., 2 per cent; codfish (Gadidae, part probably *Boreogadus saida*), 30 percent; miscellaneous fish, 25 percent; polychaetes, apparently Nereidae, 4 percent; copepoda and undetermined crustacea (which may have come from the stomach of a party-digested fish), trace.

From the size of the stomachs of the two juvenile birds, taken at Igloolik Island, it would appear that the birds were probably three-fourths grown. It is evident that the food of adults and juveniles varies considerably. Perhaps because the young are less agile and therefore less expert as fishermen, they consume fewer fish. In the two birds examined a greater variety of food was noted than in the adults. It was surprising to find that a moss of the family Hypnaceae made up 43 percent and 33 percent respectively of the two meals. It was noted that all the moss was in the gizzard and from appearance it had

been there for some time. Perhaps in this group of birds the effects of digestive action are less rapid on plant than on animal substances. Feathers are often found in quantity in the stomachs of loons and grebes, yet their function is not definitely known. Some have believed that they serve to protect the stomach walls against the sharp fish bones. It is not known whether the moss in these juvenile birds' stomachs was serving as a source of food, or, similarly, as a protection to the tender, growing gastric organ against the sharp fish-bone fragments.

The stomachs and gullets of both juveniles were well-filled and may be thus summarized: Tomcod (*Microgadus tomcod*), 59.5 percent; sculpin (*Cottidae*), 5 percent; polychaetes, apparently Nereidae, 2 percent; squid (*Loligo* sp.), 0.5 percent; moss (Hypnaceae) plant fiber, 38 percent; gastropods, trace; crustacea, including amphipoda and schizopoda (which may have been taken by the fish), trace.

Fulmarus glacialis glacialis (Linnaeus). Atlantic Fulmar.

Because the Biological Survey has no other record of a stomach examination of the Atlantic fulmar it is to be regretted that only one well-filled stomach of this bird was submitted for examination. It was collected at 61° north latitude and 32°10′ west longitude. This stomach contained the rather indigestible fragments of the lenses of fish eyes from a preceding meal, amounting to 1 percent of the total food content. Fragments of two squid (*Loligo pealei*) made up 11 percent of the food consumed, and finely ground fragments of an unidentifiable mollusk, 1 percent. The remains of 52 marine worms (Nereidae) formed the bulk of the meal, amounting to 86 percent of the total stomach content. Wood fibers and vegetable debris constituted the remaining 1 percent. Many small parasitic gizzard worms (Nematodes) were also found in the stomach. Two bird lice collected from the bird's plumage were identified by Dr. H. E. Ewing of the Bureau of Entomology as *Ancistrona vagelli* Fab.

Branta leucopsis (Bechstein). Barnacle Goose.

Only one stomach of the rare barnacle goose was included, and it was only about one-fourth filled with finely ground vegetable fiber. Of this, 40 percent was sedge (*Scirpus* sp.), 35 percent grass fiber (probably *Poa* sp.,), and the remaining 25 percent was unidentifiable. Sixty-one percent of the total stomach content consisted of fine sand. Løppenthin (6, p. 42) in his studies of Greenland birds states that he found grass, leaves, and stems of serpentgrass (*Polygonum viviparum*) and mountain sorrel (*Oxyria digyna*) in stomachs of this species.

Clangula hyemalis (Linnaeus). Old Squaw.

One stomach of the old squaw, or long-tailed duck, was obtained from the far north (Cape Frigid) and unfortunately it was too nearly empty to shed much light on the normal food preferences. The following items, however, were noted: Fragments of midge (Chironomidae) larvae; soft-bodied crustacea too finely comminuted for identification; sessile barnacles (Balanidae); limpet shells (*Acmaea* sp.); bivalves (pelecypoda) too finely broken to indicate species; seed fragments and plant fiber of sedge, probably *Carex* sp.; moss; and undetermined plant fiber. A fairly large series of stomachs of this attractive bird, examined in the Biological Survey, indicates that it feeds largely on crustaceans and mollusks.

Somateria mollissima borealis (Brehm). Northern Eider.

Information obtained from examination of five well-filled stomachs of the northern eider, collected at Clavering Island, northeast Greenland, on August 6, and compared with two stomachs collected on the New England coast in February and March of earlier years, suggests that this northern duck consumes a higher percentage of fish in summer than it does in winter. Furthermore, these five examinations indicate that this species probably eats more fish than do other eider ducks. Fishes of the family Cottidae (sculpin) were found in each of the five stomachs examined and ranged from 2 percent in one stomach to 79 percent in another, with an average of 26 percent of the total food content for the five stomachs. The number of individual fishes eaten varied from 1 to 25, with two birds each consuming the latter number.

As would be expected, mollusks constituted the largest percentage of the food, averaging 65 percent of the total. In bulk this was nearly equally divided between bivalves and univalves, the former averaging 33.4 percent and the latter 31.6 percent. A species of soft-shelled clam (*Mya* sp.) occurred most frequently and amounted to 16 percent of all food taken. Other bivalves, occurring in about the order of their importance, were the arctic rock-borer (*Saxicava arctica*), the common edible mussel (*Mytilus edulis*), and another mussel (*Crenella* sp.). Of the univalves, the whelks (*Buccinum* sp. and *Tritonofusus* sp.) occurred in each of the five stomachs and averaged 5.6 percent and 3 percent respectively of the total food content. A species of moon shell (*Natica* sp.) occurred in four stomachs and a bubble shell (*Bulla* sp.) occurred in one. Gastropods too thoroughly disintegrated to be accurately named made up 20 percent of the total food consumed.

Soft-bodied crustacea formed 7.2 percent, amphipoda (mainly *Atylus carinatus* and *Corophium* sp.) being most important. Fragments of cumaceans and isopods were recognizable in two of the stomachs.

Fragments of the following minor items made up 0.4 percent of the total food: Protozon (Foraminifera); worms (Annelida); starfish (Asteroidea); and beetles (Coleoptera). Vegetable food, consisting of sedge and moss plant fiber and algae, formed 1.4 percent.

Gravel is found in practically all duck stomachs, and in these five northern eiders, it made up 11.6 percent of the total stomach content. This, however, was not figured in the food percentages. A few feather fragments—most probably from the bird's own plumage—were found in one stomach. Feather fragments are frequently found in the stomachs of many birds, and particularly is this true of most waterfowl.

The five stomachs examined contained an average of more than 12 items per stomach. In contrast to this, the two winter birds collected along the New England coast contained only mollusks. One of these was filled with the common edible mussel (*Mytilus edulis*) and the other, which was nearly empty, contained fragments of the common mud snail (*Nassa obsoleta*).

Falco rusticolus candicans (Gmelin). White Gyrfalcon.

Five stomachs of the white gyrfalcon were obtained during the third expedition on different dates in August and September at various points on the Melville Peninsula. The stomach and small intestines of one bird were entirely empty of food, but contained many tapeworms.

Of the other four birds, one had made its entire meal on 2 collared lemming mice (*Dicrostonyx rubricatus richardsoni*) and another had made 97 per cent of its meal on 3 of these rodents, a horned lark (*Otocoris alpestris*) making up the remaining 3 percent of the food. The Melville Peninsula is

regarded as representing the northern border of the range of this rodent. The third gyrfalcon had in its stomach the remains of one red-backed mouse (*Evotomys* sp.) but, unfortunately, digestion had proceeded too far to permit accurate specific identification. *Evotomys gapperi*, according to Preble (8, pp. 50–51), is the species extending north to the Fort Churchill area. His brother, Alfred E. Preble, according to the report (Preble, 1902, p. 51), collected one specimen 15 miles north of this locality. It is not known what race occurs in the Melville Peninsula area, a region from 600 to 900 miles north of the record cited by Preble, which is the northernmost record in eastern North America. It is not improbable therefore that the specimen obtained from the falcon's stomach, which marks a notable extension of the range of this genus, is a new race or species of *Evotomys*.

The fourth gyrfalcon had made its entire meal of a luckless willow ptarmigan (*Lagopus lagopus albus*). While it is evident from the limited data available that this raptor does not shun bird food, the facts also indicate that rodents likewise are taken in numbers and probably are equally acceptable as an article of diet. Most published comments of the food habits of this bird would lead us to believe that only game and other birds enter into its diet. Bendire (1, p. 282) writes that "The natives assured me that they [the falcons] repair to the rugged mountains . . . to breed, and that they fed their young on the rock ptarmigan, which also seek that region for the same purpose. As a rule, these rocky cliffs are the summer homes of innumerable waterfowl, on whose young, as well as on ptarmigan, they prey to a great extent during the season of reproduction." Hagerup (3, pp. 292–293) writes of ptarmigan serving as the source of food for the bird in southern Greenland. Kumlien (5, p. 84) in his account of arctic American birds states that this falcon subsists wholly on ptarmigans and hares during the winter, and that while on his frequent excursions upon Disko Island he often had opportunity of witnessing the hawk preying upon jaegers, kittiwakes, and other birds. He added that he was surprised that this predator does not possess swifter powers of flight and stated that "their success seems to depend more upon a stubborn perseverance than alacrity of flight." Macmillan (7, p. 409) concludes that it feeds on eider ducks, Mandt's guillemots, ptarmigan, dovekies, and arctic hares. Other writers also mention that birds form its principal source of food. Stomach examination, however, indicates that rodents and other small mammals enter prominently into the species' bill of fare.

Falco peregrinus anatum (Bonaparte). Duck Hawk

Two young birds taken on the Barrow River, Melville Peninsula, August 29, 1933 were available for food habits study. One bird had made its entire meal on a Richardson collared lemming (*Dicrostonyx rubricatus richardsoni*) while the other had its stomach filled with bird bones and feathers, 40 percent of which was from a phalarope, apparently *Phalaropus fulicarius* and 60 percent from a red-backed sandpiper (*Pelidna alpina sakhalina*).

Lagopus rupestris reinhardti (Brehm). Reinhardt's Ptarmigan.

The contents of three stomachs with crops of Reinhardt's ptarmigan, collected August 6, at Clavering Island, were on hand for stomach analysis. All these apparently were fairly well filled, the contents indicating that this subspecies has food habits much in common with other varieties of ptarmigan. They are all highly vegetarian and seem to choose the vegetative

and succulent parts of many herbs and shrubs. It is interesting to note that each ptarmigan collected for this study had taken a trace of insects or spiders, yet of the total food content, animal matter equalled only 0.3 percent, with 2 percent as a maximum for one stomach. This bird had taken three species of flies, dungflies (*Scatophaga furcata*), dance flies (*Rhamphomyia* sp.) and *Spilogona* sp. and one spider (*Dictyna* sp.). One other bird had taken one ant (*Formica* sp.) and one fly (*Spilogona* sp.).

Bulblets of serpent-grass (*Polygonum viviparum*) were the dominant item, averaging 44.8 percent of all food consumed. One crop contained no fewer than 2,300 of these bulblets, which formed 100 percent of the food, while another had consumed more than 1,200, making it 87 percent of the meal. The flowers with mature akenes and leafy fragments of White Mountain avens (*Dryas octopetala*) ranked second in importance, averaging 19.4 percent of the total food of the three birds and amounted to 48 percent of the meal of one. The scales, spikes, and akenes of short-leaved sedge (*Carex misandra*), constituting 18.9 percent of the total average, made this species only slightly less important. One stomach contained about 500 akenes and fragments of probably 20 spikes of this species of sedge, which was 86 percent of that meal. The other contents were: Buds, leaves, and stems of an artic willow (*Salix* sp.), 5.1 percent; seeds of alpine bearberry (*Arctostaphylos alpina*), 3.3 percent; leaves and stems of purple saxifrage (*Antiphylla oppositifolia*, 3.1 percent; seeds and fruiting bodies of sedge (*Carex nardina*), 2.8 percent; fruiting and leafy portions of spiked wood-rush (*Juncoides spicatum*), horsetail (*Equisetum* sp.), sandwort (*Arenaria* sp.), crowfoot (*Ranunculus* sp.), twisted whitlow grass (*Draba incana*), hairy lousewort (*Pedicularis hirsuta*), lousewort (*Pedicularis* sp.), speedwell (*Veronica* sp.), 2.3 percent.

There was an average of 12 species of food items per bird. While 17.7 percent of the total stomach and crop content was gravel, this was not computed as a part of the food contents.

Arenaria interpres interpres (Linnaeus). European Turnstone.

From an examination of three stomachs, collected August 7 at Hudson Land, northeastern Greenland, it would seem that the arctic individuals of the European turnstone are more or less omnivorous in their feeding habits. These three birds contained an average of twelve species of items per stomach with a total of twenty-one. The three stomachs contained 74.67 percent animal tissue and 25.33 percent plant fiber. Gravel (not included in food percentages) amounted to 22 percent of the total stomach contents. Those food items found in excess of 1 percent of the total, were: Crustaceans (mainly amphipods), 23.3 percent; diptera (two-winged flies, mainly craneflies Tipulidae and Anthomyiidae), 20.9 percent; wood and other plant fiber, 13 percent; algae, 12.34 percent; sea-squirt, or ascidian, 9.3 percent; spiders and salt-water mites, 6 percent; brittle-stars (Ophiuroidea), 5 percent; bees and wasps (hymenoptera, mainly Ichneumonidae), 3.67 percent; beetles (coleoptera), 2.67 percent; butterflies (Lepidoptera), 1.7 percent; snails (gastropoda), 1 percent. Fragments of fish and a marine worm made up the remaining 1.12 percent.

Løppenthin (6, p. 55) found midges, snakeflies, the larvae of a cranefly (*Tipula* sp.), larvae of caddice flies (Trichoptera), a few ichneumon flies (Ichneumonidae), a spider, fragments of a phalangid (*Mitopus morio*) which previously had not been recorded so far north in eastern Greenland and gravel in the stomachs of a number of birds examined.

Calidris canutus rufus (Wilson). American Knot.

An examination of the stomach content of four adult and two juvenile American knots collected on the second expedition at Parker Snow Bay, west Greenland, revealed that this bird has a varied diet. The four adults had subsisted largely upon plant fiber and rootlets, which they had finely pulverized. Each bird had made most of its meal on this material. It was somewhat surprising that vegetable substance entered so prominently into the bill-of-fare, forming 93 percent of the adults' and 24 percent of the juveniles' food. Dipterous forms, largely larvae, were the principal animal food of the young birds, while snails (gastropoda) and undetermined fragments of mollusks comprised the chief source of protein food for the adults.

A summary of the food of these birds follows:

Four adults.—Fragments of gastropods and unidentified mollusks, 6.25 percent; midges (Chironomidae) and other flies (Diptera), mostly larvae, 0.75 percent; spider, trace; crustaceans, trace; fish (taken by one bird), trace; bird louse (*Degeeriella* sp.), trace; moss plant fiber, 1.25 percent; Phippsia grass (*Phippsia* sp.), 16.25 percent; undetermined plant fiber and rootlets, 75.50 percent.

Two juveniles.—Fragments of midges (Chironomidae), mostly larvae, 27 percent; salt flies (Ephydridae), 17.50 percent; two-winged flies (Diptera), too broken to permit more specific identification, 11.50 percent; bees and wasps (Hymenoptera), 6 percent; spiders, 2.50 percent; univalves (gastropoda) and undetermined mollusca, 4.50 percent; amphipoda, 4 percent; moss, 1 percent; meadow grass (*Poa* sp.), foxtail grass (*Alopecurus* sp.), cinquefoil (*Potentilla* sp.), and willow (*Salix* sp.), each 0.50 percent; fragment of undetermined grass (Gramineae), 10 percent; sedge (*Carex* sp.), 4 percent; and undetermined plant fiber and rootlets, 10 percent.

K. Henriksen, according to Løppenthin (6, p. 58) found the birds in northeast Greenland feeding on midges and stems of serpent-grass (*Polygonum viviparum*).

Phalaropus fulicarius (Linnaeus). Red Phalarope.

Two red phalaropes were collected by the third expedition on July 20, 1933 at latitude 61° north and longitude 24°20′ west, but unfortunately the stomachs of both birds were only partly filled, although several items of food were noted. The following items in their approximate percentages were recorded for the two separate birds: No. 1. Fragments of lace-winged flies (Chrysopidae, probably *Chrysopa* sp.), two-winged flies (Ephydridae, Chironomidae, Syrphidae, Asilidae, *Megaselida* sp., Dolichopodidae, and undetermined Diptera), squash bugs (Coreidae) and other Hemiptera, sawflies (Tenthredinidae), grasshoppers (Orthoptera) and beetles (Coleoptera), 90 percent; pulp of some seeds, probably sedge (*Carex* sp.), and vegetable debris, 10 percent. No. 2. Fragments of waterboatmen (Corixidae), 25 percent; fragments of midges (Chironomidae) and robber flies (Asilidae), 25 percent; seed pulp and one seed of sedge (*Carex* sp.), 50 percent.

Stercorarius parasiticus (Linnaeus). Parasitic Jaeger.

The stomach of one July specimen, taken in the Greenland Sea, at 73°32′ north latitude and 17°10′ west longitude, contained the remains of five or more tomcod (*Microgadus tomcod*), forming 41 percent of the meal. The remains of many crustacea, mainly amphipods (*Themisto libellula*) made up the remaining 59 percent. It is not known whether this food or the meals of

the two succeeding species were captured direct or resulted from forced regurgitations by other birds.

Løppenthin (6, pp. 84–85) states that in an adult female's stomach a lemming mouse was found. A juvenile bird had 3 small fishes in its gullet, while its stomach contained fragments of fish and a lemming mouse besides pieces of grass, stems, and gravel.

Stercorarius longicaudus Vieillot. Long-tailed Jaeger.

Two specimens of the long-tailed jaeger were collected on the same date and in about the same part of the Greenland Sea as the preceding species. Like the parasitic jaeger, these birds also had their stomachs filled with fish and crustaceans, suggesting that their food habits, when the birds occur in the same general region, are very similar. One stomach contained the remains of ten fish (seven of which were tomcod) besides considerable crustacean material. Fish (tomcod and an undetermined species) formed 29.5 percent of the total, while the following crustaceans made up the remaining 70.5 percent: schizopods (*Thysanoessa inermis*), 37.5 percent; amphipods, including *Themisto libellula*, 17.5 percent and *Gammarus locusta* 2.5 percent; and unidentifiable soft-bodied crustaceans, 13 percent.

Løppenthin (6, p. 93) comments that numerous items are taken as food by these birds. In good lemming years he says the birds subsist largely on these creatures. In other years as was the case in 1930, he states that they are forced to search for other food. He reports that the contents of one stomach of a bird taken near a lake was full of insects, lemmings, and gravel. A whelk (*Buccinum* sp.) was found in the stomach of another. Still another contained a cutworm (noctuid) larva, 1 adult and 1 larva of the brush-footed fly (*Argynnis* sp.), 2 *Dasychira groenlandica*, and a few craneflies (*Tipulsa* sp.), along with the remains of a lemming. One bird was observed to contain a green berry in its bill. He cites an example of this jaeger pursuing a snow bunting and comments that these and other small birds are occasionally taken.

Larus hyperboreus Gunnerus. Glaucous Gull.

Ludwig Kumlien, in his report on the Howgate polar expedition of Arctic America (5, p. 97), noted that the glaucous gulls are extraordinarily greedy and voracious, that "nothing in the animal kingdom seems to come amiss to them. . . . Eggs, young or disabled birds, fish, and crustaceans are their common fare." He states further that they are very fond of feeding upon seal carcasses.

Results obtained in the present investigation of six well-filled, and one other stomach collected in July between 73° and 75° north latitude and 15° and 17° west longitude, and three stomachs taken in the same month at Cape York, northern Greenland, along with two taken in August at Dalrymple Island, northern Greenland, bear out this bird's reputation of being a scavenger and quite an omnivorous feeder. The results also suggest that depredations upon other bird life may at times be serious. Of the number of birds collected, seven of the full stomachs were from adults and four from juveniles.

Characteristic of most other species, the juvenile birds had consumed a much larger variety of foods than had the adults. Remains of other birds were also more numerous in the juvenile stomachs, suggesting that these birds had been hatched in the immediate neighborhood of other seafowl.

TABLE 1.—THE FOOD OF THE GLAUCOUS GULL

	Gull (ovum) feathers	Hydrozoa Aeurina	Crustacea (undet.)	Copepoda	Thysanoessa inermis	Diptera larvae	Mollusca (undet.)	Mytilus edulis	Lottia	Bronchyo-centrotus	Pisces (undet.)	Cottidae	Microgadus tomcod	Aves (undet.)	Aves eggs	Cephus grylle mandti	Alle alle	Lemmus trimucronatus	Phoca-dina (carrion)	Algae (undet.)	Musci Poa Grass sp.	Alopecurus	Carex	Cerastium	Plant (undet.)	Species of Items per Stomach
Adults	tr[a]		tr				tr		18		27	5	50						63						5
192873	tr		18							tr	3		16												6
192874			1								2	98	99					1							4
192876			1																						2
192877	tr		tr							tr	15	85					96					tr		tr	5
197979			tr											100											2
197980	tr		tr																						3
197981																									1
Ave. %	tr		2.9				tr		2.6	tr	6.7	26.8	23.6	14.3			13.7	0.1	9						4.1
Juveniles																									4
192871	tr		10	tr	15								75												2
192872	tr		1			tr		1		1			99												11
197982	tr													38	2	25	25			6	3	1	1	2	12
197983		tr												88	2					2				3	
Ave. %	tr	tr	2.8	tr	3.7	tr	tr	0.3		0.2			43.5	31.5	1	6.3	6.2		2	2	0.8	0.2	0.3	1.2	7.3

[a] Trace.

The accompanying table summarizes the food of the birds as analyzed in the Biological Survey Laboratory. Where genus only is given species could not be determined.

From the tabulation it is noted that coarse fish were first in importance with the adults, forming more than half (57.14 percent) of the total food consumed; while birds were second, amounting to 28 percent. It was somewhat surprising to find that these two items were almost of equal value with the young birds, fish (tomcod) totaling 43.50 percent, and birds comprising 45 percent. The presence of decayed seal (Phocidae) flesh confirms the bird's reputation as a scavenger and carrion feeder. The kelp and other plant substances taken by the young birds were taken incidental to the process of learning to feed and forage for themselves.

Pagophila alba (Gunnerus). Ivory Gull.

Only one heavily gorged stomach and gullet of the ivory gull, taken at latitude 74°05′ north and longitude 17°15′ west, was submitted for examination. Fragments of a tomcod made 1 percent of the meal, while the remaining 99 percent consisted of fragments of soft-bodied crustaceans as follows: 115 schizopods (*Thysanoessa inermis*), 95 percent; 5 amphipods (*Apherusa glacialis*), 1 percent; copepods, trace; other undetermined crustaceans, 3 percent.

Rissa tridactyla tridactyla (Linnaeus). Atlantic Kittiwake.

The single stomach of the Atlantic kittiwake, taken June 22, at latitude 62°30′ north and longitude 29°07′ west was fairly well filled with fish bones, predominantly tomcod and a species resembling the Engraulidae. Ninety-nine percent of the total food content was fish, while fragments of one undetermined damsel-fly (Zygoptera) made up the remaining 1 percent. In addition there was a trace of plant fiber.

Sterna paradisaea Linnaeus. Arctic Tern.

Only three stomachs of the Arctic tern from the north Greenland seas were submitted for examination. These were collected in July between 73° and 74° north latitude and 15° and 17° west longitude. These contained 33.67 percent fish, mainly tomcod (*Microgadus tomcod*); 65.67 percent soft-bodies crustaceans, mainly schizopods (*Thysanoessa inermis*); and a fraction of one percent of vegetable debris. One of these 3 birds was a juvenile that had fed solely on crustaceans, mostly *Thysanoessa inermis*.

Uria lomvia lomvia (Linnaeus). Brunnich's Murre.

Of seven stomachs collected in July 1931, between 72° and 73° north latitude and 13° and 18° west longitude, only three were well-filled. On the second expedition two birds of this species, collected at Parker Snow Bay, western Greenland, were submitted—only one being full. On the third arctic trip, 34 additional birds were collected near Hudson Strait, Resolution Island and Salisbury Island. Of these, 31 were sufficiently full to be used in the computation of food percentages.

From an analysis of these stomachs it is evident that Brunnich's murre

subsists principally on but few species of items. One amphipod species (*Themisto libellula*) occurred in all but one stomach and comprised 90.37 percent of the entire food consumed. Nearly two-thirds of the birds had taken this large amphipod to the extent of 100 percent of their meals, a number consuming no fewer than a hundred individuals. In a few of these stomachs other items occurred, but amounted to only a trace in the food. Other amphipods amounting to 1.40 percent included *Gammarus locusta*, *Pseudalibrotus nanseni*, and *Gnathia maxillaris*. The schizopod (*Thysanoessa inermis*) was apparently acceptable when available, as one murre had consumed more than 125 of these creatures, comprising 87 percent of its meal. But four of the birds had fed on these crustaceans and in total they formed 5.51 percent of the entire food intake. Undetermined soft-bodied crustaceans formed 1.20 percent, and in the aggregate, crustaceans formed 98.48 percent of all food consumed by the 35 birds. Fish, mostly sculpin (Cottidae), were fed upon by three birds and formed 1.06 percent of the food. The remaining 0.46 percent of the average meal consisted largely of polychaete worms, probably Nereidae. While their mandibles occurred in 9 stomachs, they usually formed but a trace in the food. Plant fiber occurred as a trace in two stomachs.

The principal items noted in the stomachs but not figured in the computations included squid (*Loligo* sp. which formed the principal item in one stomach one-tenth full), undetermined crustaceans, and fish.

Alle alle (Linnaeus). Dovekie.

Seven well-filled stomachs with five full gullets from dovekies collected on ice floes early in July from the north Greenland polar seas (between lat. 72° and 74° N. and long. 13° and 18° W.) were available for the present study. They reveal that this species shares the well-known propensity of many northern sea birds to feed extensively on soft-bodied crustaceans, as all but a mere trace of food in each of two stomachs consisted of these small aquatic creatures. One stomach contained a few fragments of fish bones and another a trace of an unidentifiable bone. A common and apparently an easily obtainable schizopod (*Thysanoessa inermis*), constituted the dominant item in all the gullets and in five of the stomachs, averaging 57.86 percent of the total food consumed by the seven birds. One bird had devoured no fewer than 133 of these reddish shrimp-like creatures while other stomachs showed remains of 75, 56, 53, and 33, respectively. Amphipods (Hyperiidae, *Gammarellus* sp. and *Themisto libellula*) amounted to 16.57 percent of the total, while fragments of unidentifiable crustaceans, probably consisting largely of the schizopods and amphipods herein listed, made up the remaining 25.57 percent of the total food consumed. It was interesting to note that a trace of feathers was found in four of the seven stomachs.

Cepphus grylle grylle (Linnaeus). Black Guillemot.

If the two available July stomachs of the black guillemot can be taken as a criterion, its summer food in the North Atlantic consists of an unusually high percentage of fish. The two stomachs contained 79.5 percent tomcod (*Microgadus tomcod*), 12 percent undetermined fish bone fragments, and 8.5 percent fragments of amphipods and undetermined crustaceans.

Cepphus grylle mandti (Mandt). Mandt's Guillemot.

Five stomachs of Mandt's guillemot were obtained from North Star Bay (lat. 76°33′ N.) and Dalrymple Island, northern Greenland and Wolsten-

holme, western Greenland. Of these, three were juvenile birds two of which contained but little food. The other juvenile stomach being but one-fifth full, had made 10 percent of its meal on fish, 10 percent on the gastropods (*Margarites* sp.), 8 percent on undetermined gastropods, 15 percent on the crustacean, *Harpacticus uniremis*, 25 percent on amphipoda, including *Pseudalibrotus litoralis* and Oedicerotidae, and 32 percent on undetermined crustaceans, probably mostly amphipods. The other juvenile birds had taken fish, squid, crustaceans, gastropods, annelid worms, and plant fiber.

The two adult birds, while consuming much of the same kinds of food, had subsisted more heavily on fish. One bird had consumed 14 sculpins (Cottidae), representing 3 species. Undetermined fish comprised 4 percent of the total while crustaceans, including *Spirontocaris polaris*, *S. fabricii*, *S. gaimardii*, *Harpacticus uniremis*, and *Amenophia peltata*, constituted 37 percent. Bivalves, squid (*Loligo* sp.), and annelids each formed 0.50 percent of the total.

As would be expected, the two races of guillemots are similar in their food habits.

Hantzsch (4, p. 90) states that "six stomachs [of Mandt's guillemot] contained in four cases fish remains, one digested crustacean remains, unmistakable prawn remains, one *Gammarus* and one small snail." Bent (2, p. 164) asserts that "the food of Mandt's guillemot seems to consist mainly of small fishes, crustaceans, and other soft-bodied sea animals."

Corvus corax principalis Ridgway. Northern Raven.

The stomachs of two northern ravens, one taken near Parker Snow Bay and the other at Dalrymple Island, furnish evidence that this northern race is as predacious and omnivorous in its food tendencies as any of its relatives farther south. The stomach contents from the two meals are as follows: No. 1. Parts of 1 chinch bug (*Nysius groenlandicus*), trace; fragments of 5 horsefly pupae (Tabanidae), 1 percent; bird egg fragments, 2 percent; bird feathers and bone fragments not positively identified, but possibly from the dovekie (*Alle alle*), 10 percent; carrion and hair fragments of reindeer (*Rangifer groenlandicus*), 40 percent; other (?) carrion, 6 percent; moss plant fiber of 2 species, 1 percent; 88 berries and 125 additional seeds, fruit pulp, floral parts, and leafy fragments of the cowberry (*Vaccinum* [? *vitis-idaea*]), 26 percent; 20 berries, fruit pulp, and 8 additional seeds of the crowberry (*Empetrum nigrum*), 8 percent; plant fiber and floral parts of bent grass (*Agrostis* sp.), 1 percent; plant fiber and floral parts of meadow grass (*Poa* sp.), 1 percent; plant fiber of undetermined grass (Gramineae), trace; seed fragments and plant fiber of sedge (*Carex* sp.), 1 percent; leafy fragments of a heath, possibly *Cassiope* sp., trace; undetermined plant fiber, 3 percent. No. 2. Parts of bird, undetermined, 15 percent; fragment of bird egg, about the size and color of that of a duck, 1 percent; fragments of mammalian carrion, 10 percent; fragments of an undetermined insect, trace; fragment of mollusks, trace; 9 berries and 11 additional seeds of the crowberry (*Empetrum nigrum*), 60 percent; moss plant fiber, 1 percent; undetermined plant fiber, 13 percent.

Mustela arctica arctica (Merriam). Weasel.

But one partly-filled stomach of this weasel was available for laboratory study and it contained fragments of a single item—a lemming mouse (probably *Lemmus trimucronatus*).

Citellus parryii parryii (Richardson). Hudson Bay Ground Squirrel.

Five stomachs of the Hudson Bay ground squirrel show that, like its more southern congeners, it is primarily a vegetarian. While a fairly large number of plant foods were consumed, two items—vetch (*Astragalus* sp.) and sedge (*Carex* sp.)—appeared in each stomach examined, and formed 73.40 percent and 14.20 percent respectively of all food taken. Smartweeds (*Polygonum* sp.) formed 8 percent, while wood rush (*Luzula* sp.), rush (*Juncus* sp.) and rose (Rosaceae) formed 0.6, 0.2, and 0.2 percents respectively. Unidentified plant debris aggregated 1 percent. Other vegetable foods occurring as a trace included: Moss, grass (Gramineae), waterbuttercup (*Ranunculus* sp.), cinquefoil (*Potentilla* sp.), Labrador tea (*Ledum groenlandicum*), and blueberry (*Vaccinium* sp.).

Four of the five ground squirrels had fed to a limited extent on the larvae of craneflies (*Tipula* sp.) which averaged 2.40 percent of the food. One animal also had the remains of fish from a preceding meal in its stomach. This, however, formed but a trace of the total food.

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BOTANY.—*Three new grasses from Polynesia.*[1] JASON R. SWALLEN, Bureau of Plant Industry.

The following new species were in a large collection of grasses recently received for study from the Bernice P. Bishop Museum, Hawaii. One was collected on the island of Rapa, one on Raiatea, Society Islands, and the other on Aiwa, Fiji Islands.

Aristida aspera Swallen, sp. nov.

Perennis; culmi dense caespitosi, erecti, nodis geniculati, asperi, 40–60 cm alti, ramis dense fasciculatis; vaginae internodiis elongatis breviores, scaberulae; ligula 0.2 mm longa; laminae planae vel involutae, flexuosae vel falcatae, 2–8 cm longae, 1–2 mm latae, glabrae; paniculae 3–10 cm longae, ramis appressis paucifloris remotis; spiculae appressae vel divergentes;

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glumae mucronatae, 1-nerves, prima 4.5 mm longa, secunda 6.5 mm longa; lemma 7–8 mm longum, glabrum, callo 0.5 mm longo, dense piloso; aristae 7–9 mm longae, teretes, scabrae.

Perennial; culms in dense hard clumps, erect from short knotty rhizomes, sometimes geniculate at the nodes, 40–60 cm tall, somewhat flattened, minutely nodulose roughened, freely branching from all the nodes, the branches often in dense fascicles; sheaths much shorter than the elongate internodes, scaberulous; ligule minutely lacerate, 0.2 mm long; blades flat, becoming involute, especially toward the tip, firm, more or less flexuous or falcate, 2–8 cm long (usually less than 5 cm), 1–2 mm wide, glabrous; panicles 3–10 cm long, the branches rather distant not overlapping, few-flowered, appressed; spikelets appressed to somewhat spreading, the pedicels 2–7 mm long; glumes mucronate, 1-nerved, the first 4.5 mm, the second 6.5 mm long, glabrous; lemma 7–8 mm long slightly narrowed toward the tip, glabrous; callus 0.5 mm long, blunt, rounded, densely short-pilose; awns 7–9 mm long terete, scabrous, equally spreading.

Type in the Herbarium of Bernice P. Bishop Museum, collected on grassy slopes of Atanui Valley, altitude 100 m, Rapa, Polynesia, July 24, 1934, by F. R. Fosberg (no. 11620). Duplicate type in the U. S. National Herbarium.

Aristida aspera is related to *A. caput-medusae* Domin which has a shorter panicle (3–6 cm long) with short, approximate, abruptly divergent branches, and smooth culms. Locally called "tine."

Garnotia mucronata Swallen, sp. nov.

Perennis; culmi dense caespitosi, 10–30 cm alti, glabri; vaginae glabrae internodiis longiores; ligula truncata 0.3 mm longa; laminae planae, lanceolatae, pungentes, glabrae, 2–6 cm longae, 2–6 mm latae, marginibus scabris; panicula 4–12 cm longa, stricta, ramis fasciculatis appressis, ad 3 cm longis; spiculae binae 4–5 mm longae basi breviter pilosae; glumae 4 mm longae; 3-nerves, acutae vel acuminatae; lemma 4 mm longum, 3-nerve, glabrum mucronatum vel breviter aristatum; palea hyalina lemma aequans.

Perennial; culms densely tufted, erect, 10–30 cm tall, glabrous; leaves crowded toward the base in a dense cluster; sheaths rounded on the back, glabrous, the lower ones short, overlapping, the uppermost elongate; ligule hyaline, truncate, 0.3 mm long; blades flat, or the margins inrolled, firm, lanceolate, sharp-pointed, 2–6 cm long, 2–6 mm wide, glabrous, the margins scabrous; panicle 4–12 cm long, strict, the branches in rather distant fascicles, appressed, the lowermost as much as 3 cm long; spikelets paired, 5 mm long, including the awn, the hairs at the base short and inconspicuous; pedicels triangular, unequal, the lower about 1 mm long, the upper 2–3 mm long; glumes equal, 4 mm long, acute or acuminate, 3-nerved, the nerves of the first glume scabrous, those of the second glume nearly glabrous; lemma firm, 4 mm long, 3-nerved, glabrous, awn-pointed or awned, the awn not more than 1.5 mm long; palea thin, hyaline, equaling the lemma.

Type in the Herbarium of Bernice P. Bishop Museum, Hawaii, collected on a high moor, Temibani Plateau, alt. 700 m, Raiatia, Society Islands, Oct. 5, 1934, by Harold St. John (no. 17295). Duplicate type in the U. S. National Herbarium. Endemic to Raiatea.

Two other endemic species of *Garnotia* have been described from Raiatea, *G. raiateensis* Moore and *G. depressa* Moore. In the first of these the blades are as much as 8 cm long and not more than 4.5 mm wide, and in the second the blades are involute, not more than 3.5 cm long, while the blades in *G. mucronata* are flat, comparatively short and broad, not more than 6 cm long and as much as 6 mm wide. Furthermore the lemmas in *G. mucronata* are awnless or nearly so whereas those of *G. raiatensis* and *G. depressa* bear slender awns 4–6 mm long.

Another collection, St. John 17298, from the type locality, also belongs to this species.

Eragrostis scabriflora Swallen, sp. nov.

Perennis; culmi erecti dense caespitosi, graciles, simplices vel ramosi, 20–60 cm alti, glabri; vaginae internodiis breviores, glabrae, in ore dense pilosae; ligula truncata lacerata 0.3 mm longa; laminae erectae vel adscendentes, subinvolutae, 5–15 cm longae (inferiores reductae), infra glabrae supra scabrae; paniculae 3–15 cm longae terminales et axillares ramis solitaribus appressis, ad basin dense floriferis, ad 2 cm longis; spiculae 6–18-florae appressae; glumae acutae 1.5 mm longae; lemma 2 mm longum subacutum, minute scabrum; palea lemma aequans carinis breviter ciliatis.

Perennial; culms erect, densely tufted, slender, wiry, simple or branching from the middle nodes, 20–60 cm tall, glabrous; sheaths much shorter than the internodes, glabrous with a conspicuous dense tuft of hairs at the mouth; ligule truncate, finely lacerate, 0.3 mm long; blades firm, erect or ascending, 5–15 cm long, the lowermost much reduced, flat or loosely folded, smooth below, scabrous and with a few long hairs at the base on the upper surface; panicles 3–15 cm long, the branches solitary, appressed, densely flowered from the base, rather distant in the lower part of the panicle, becoming approximate toward the summit, not more than 2 cm long; spikelets short-pediceled, appressed to the branches, 6–18 flowered (usually 10–12 flowered), the rachilla continuous; glumes acute, 1-nerved, about 1.5 mm long, scabrous on the keel; lemmas 2 mm long, subacute, minutely scabrous, more so on the nerves; palea persistent, obtuse, a little shorter than the lemma, shortly ciliate on the upper half of the keels.

Type in the Herbarium of Bernice P. Bishop Museum, Hawaii, collected on "bare spots in wooded basin and on limestone ridges, alt. 25–40 m, Aiwa (E)," Fiji Islands, August 30, 1924, by E. H. Bryan, Jr. (no. 528). Duplicate type in the U. S. National Herbarium.

This species has also been collected "on bare hillsides (dry) and moist hollows (luxuriant), alt. 10–60 m, . . . Olorva," Fiji Islands (Bryan 520).

This grass is apparently the one which Summerhays and Hubbard[2] refer to *E. elongata* (Willd.) Jacq. In that species, however, the lemmas are smooth and abruptly acute, the panicle branches are longer, scarcely densely flowered, and usually spreading. The sheaths also lack the tuft of hairs at the mouth which is a conspicuous character of *E. scabriflora*.

[2] SUMMERHAYES, V. S. and HUBBARD, C. E. *A supplement to the grasses of the Fiji Islands.* Kew Bull. Misc. Inf. 1930: 262. 1930.

PLANT PHYSIOLOGY.—*Inhibition of arsenic injury to plants by phosphorus.*[1] ANNIE M. HURD-KARRER, Bureau of Plant Industry. (Communicated by M. A. McCALL.)

The inhibiting effect of sulphur on the absorption of selenium by wheat, and the quantitatively reproducible relation between the two elements at any given degree of injury to the plant,[2] suggested a search for other pairs of elements similarly related. It appeared from the quantitative nature of the interrelationship that the phenomenon might be a simple mass effect resulting from the inability of the plant to differentiate between the two elements, because of their chemical similarity, in the processes of absorption, translocation and synthesis. The possibility of a generalization covering other similarly related pairs of elements was then apparent.[3]

Reasoning by analogy, from the positions of selenium and sulphur in Group VI of the periodic table, the first pair of elements chosen for investigation were arsenic and phosphorus, which occupy corresponding positions in the adjacent Group V.

The experiments were conducted with wheat seedlings germinated on blotters and transferred to flasks containing 600 cc of nutrient solution. Three different nutrient solutions were used, containing equal concentrations of calcium, magnesium, potassium, sulphur, nitrogen, and iron but with differing concentrations of phosphorus, viz., 10, 60, and 120 parts per million as calcium monophosphate. The calcium was equalized by varying the amounts of calcium chloride. Control plants grown in these solutions were alike, showing that the differences in chlorine and phosphorus were insufficient to visibly affect growth over the period of an experiment—about two weeks.

In several successive experiments it was found that arsenic added to these solutions at a rate of 30 p.p.m. as sodium arsenate killed the plants where only 10 p.p.m. of phosphorus was present, injured those with 60 p.p.m. of phosphorus, but hardly affected those with 120 p.p.m. of phosphorus. These results are in conformity with the hypothesis proposed to explain the selenium-sulphur antagonism, namely, inhibition of toxicity by the presence of an excess of a chemically similar non-toxic element as a simple mass effect.

In the first two experiments the pH values of the nutrient solutions

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[2] HURD-KARRER, ANNIE M. *Selenium injury to wheat plants and its inhibition by sulphur.* Jour. Agr. Research **49** (4): 343–357. 1934. *Factors affecting the absorption of selenium from soils by plants.* Jour. Agr. Research **50** (5): 413–427. 1935.

[3] HURD-KARRER, ANNIE M. *Plant physiology involved in the problem of the selenium disease of livestock.* This JOURNAL **25**: 335–336. 1935.

were 4.2, 3.9, and 3.6, respectively, for the low-, medium- and high-phosphorus levels. In the third experiment, the reactions were adjusted to pH 7.3, 6.2, and 6.5, respectively, by using one to two drops of strong sodium hydroxide. Acidity of the solutions was therefore not a factor in the antagonism.

Repeated attempts to inhibit arsenic injury to plants in the local clay loam by additions of phosphate have been unsuccessful. However an inhibiting effect was obtained in a sandy loam. These results suggest that phosphate applications will reduce or prevent arsenic injury to plants where the type of soil is such as to permit the phosphate to remain available. Such an effect of phosphorus might be of considerable importance in areas having soils contaminated with injurious concentrations of arsenic from sprays.

Preliminary results indicate a corresponding relationship between rubidium and potassium, the second pair of elements selected for study from their positions in the periodic table. Into the picture might possibly be fitted also the well-known calcium-magnesium antagonism. Other combinations such as calcium with strontium and with barium are being investigated.

ENTOMOLOGY.—*A new Ecuadorian fleabeetle injuring crucifers (Coleoptera: Chrysomelidae).*[1] H. S. BARBER, Bureau of Entomology and Plant Quarantine.

Prof. F. Campos R. recently submitted a sample of an apparently new species of green *Disonycha* with the statement that its larvae, in great numbers, cause damage to various kinds of cruciferous plants at Guayaquil, Ecuador. An earlier sample from the same place and observer, received in January 1918, and another sample labeled as from Chira, Peru, May 1928, G. N. Wolcott, are believed to be the same species, but host-plant records do not accompany these specimens. No description applicable to these samples has been found, and in order that a name may be available for the species a brief diagnosis is here offered together with notes from comparison with its near relatives.

Disonycha camposi, n. sp.

Length 5 mm; width 2.4 mm. Black with bluish reflection; the elytra metallic green, the occiput, pygidium, last ventral abdominal segment, distal parts of femora, and lower surface of the basal two (or three) antennal segments, yellow. Habitat: Ecuador and Peru.

Similar to *D. laevigata* Jacoby in shape, size, sculpture, and color of

[1] Received January 15, 1936.

elytra but differs in genitalic details as well as in the melanic suppression of the bright yellow color of the body and appendages, vestiges of this yellow color remaining on the basal antennal joints and the apices of all femora as well as in a transverse oval spot on top of the head and another involving the pygidium and most of the last visible sternite. The pronotum and propleurae as well as the metasternum are shining black; the first four visible sternites together with the meso- and meta-pleurae are black, opaque and clothed with fine appressed whitish pubescence. The aedeagus is of similar form and curvature to that of *laevigata* but darker brown in color of integument, shorter and more explanate apically, and the concave orificial plate is broadly truncate at apex in the type, with deceptive brown coloration suggesting apical bifurcation, whereas in *laevigata* this concave orificial plate is more attenuate and acutely pointed at apex with a brownish median area which is narrowly produced and rounded apically. The aedeagus of the also very similar *D. collata* (Fab.) resembles the above in profile, curvature, and outline, and the orificial plate displays a similar apical bifurcation of the brown sclerotization but its apex is laterally compressed, elevated and prolonged into an erect lamella. In a paratype from Peru the apex of the orificial plate is less truncate and suggests a slight unfolding of the adjacent part of the normally invaginated internal sac, the structure of which seems not to have been investigated in any species of *Disonycha*. Without such investigation the current standards of specific, subspecific, or synonymic status of available specific names can be little more than temporary opinion.

D. camposi may also be closely related to the two Colombian species, *D. exima* Harold 1876, which, it has recently been suggested, may be a prior name for *laevigata* Jacoby 1897, and to *D. steinheili* Harold 1876, but these two forms appear, from the original descriptions, to be larger and to have the pronotum and undersurface ferrugineous or testaceous.

Type ♂, allotype ♀, and eleven paratypes in the collection of the United States National Museum.

The selected holotype is one of ten specimens submitted from Guayaquil by Prof. Campos, eight of them about the end of 1917 and two in April 1935, the latter as adults of larvae injuring crucifers. Three other paratypes are labeled "No. 25–28 Chira, Peru. May 1928. G. N. Wolcott Collector."

It is a pleasure to select for this species the name of the zealous Ecuadorian who has contributed much to the knowledge of the insects of his country.